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Where to Locate Innovative Activities in Global Value Chains

DOES CO-LOCATION MATTER?

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OECD

FOREWORD

With the emergence of global value chains (GVCs), production stages have become unbundled across a growing number of countries. While R&D and innovation were traditionally among the least internationalised functions of the value chain, a growing number of firms have offshored R&D and innovative activities to foreign locations during the past decade(s). This growing internationalisation has attracted the attention of policy makers in developed as well as emerging economies.

Since MNEs are leading actors and co-ordinate GVCs while at the same time transferring technology across borders, attracting MNE investments in innovative activities (including R&D but also design and testing) may be important for the participation and upgrading of emerging economies in GVCs. Conversely, concerns have been raised in developed economies about the effects of outward investments by MNEs on the home economy in terms of R&D and innovation capabilities. A particular concern relates to the possible co-location effects between innovative and production activities; the argument is often heard that offshoring production today may result in the offshoring of R&D and innovation tomorrow.

This paper presents empirical evidence on the global patterns and trends of MNE investments during the period 2002-2011. It identifies the "pull" and "push" factors of global investments in R&D and innovation and analyses to what extent MNEs prefer to co-locate innovative activities and other value chain activities such that innovative investments are likely to follow other investments. Lastly, the paper also investigates the links and effect between investments in R&D and innovation at home and abroad.

The paper was written by Rene Belderbos, Leo Sleuwaegen and Dieter Somers of the University of Leuven and Koen De Backer of the OECD Secretariat. The Committee on Industry, Innovation and Entrepreneurship (CIIE) approved and declassified this report on 29 March 2016 as part of its work on "GVC upgrading and extensions".

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

With the emergence of global value chains (GVCs), production processes are increasingly fragmented and dispersed across different countries. This unbundling trend has recently also affected R&D and innovation. Although many MNEs still exhibit an important "home bias" in their global innovation activities, a growing number of firms have offshored R&D and innovative activities to foreign locations. Two core motivations underpin this growing internationalisation of R&D and innovation: to adapt products and processes to host country conditions and help expansions in foreign markets, and to develop new technologies and reap other benefits from foreign R&D capabilities.

The offshoring of R&D and innovation within GVCs poses new challenges to economic policy in OECD and emerging economies. How can countries attract inward R&D investments by foreign MNEs and which policies are most effective and efficient? Should outward R&D investments by MNEs be a concern for the countries in which the MNEs are headquartered? Is the more recent offshoring of R&D and innovation linked to the prior waves of manufacturing offshoring? The fear in OECD countries is that because of co-location effects between production and innovative activities, the loss of certain manufacturing/assembly activities may result in a loss of innovative capabilities (R&D, design, etc.) in the longer-term.

A detailed analysis of close to 5 000 cross-border greenfield projects in R&D and innovation in global cities over the period 2003-2011 shows that the majority of these international R&D projects concern development, design and testing, which are activities that often benefit from close proximity to MNEs' major markets. A substantial share has been going to Asian markets, with internationally connected "global" cities such as Shanghai, Beijing, Bangalore and Singapore acting as major hosts. In more recent years however - particularly after the financial crisis - this shift eastwards has somewhat slowed down and OECD countries such as the United States, Germany and the United Kingdom have attracted a growing number of international R&D investments. Another important observation is that emerging economies such as India and the People's Republic of China (hereafter "China") have themselves increasingly invested themselves in R&D and innovation activities abroad.

The analysis presented in this report focuses on the attractiveness of global cities, rather than countries, given that location decisions are taken at the city level. The evidence presented suggests the importance of international connectivity of locations, provided by airport infrastructure but also cross-border R&D collaboration. MNEs search particularly for internationally connected cities to facilitate knowledge transfer across their geographically dispersed network of affiliates. Another salient aspect is the positive role of local universities' research strengths if university research is in domains relevant to the sector of the investing MNEs. These findings imply positive effects of policy initiatives focusing on international R&D collaboration, infrastructure for global travel and transactions, and support for entrepreneurial universities.

Beyond location factors also highlighted in previous studies, cost factors are found to play an important role in MNEs' location decisions, particularly when potential locations satisfy key conditions concerning basic infrastructure. Cost factors like the average wage levels for skilled employees at the city level, the corporate tax rate, and fiscal R&D incentives are important drivers of location choice among global cities in OECD countries. The result is that (fiscal) competition between OECD countries to attract investments has increased; previous research has however shown that government support can matter especially in the final stages of the decision process but cannot compensate for the negative effects of other (more) important factors.

Cost factors are also found to be important in maintaining R&D and innovation at home. While previous studies have shown that the embeddedness of MNEs' R&D operations in the home economy discourages firms to conduct a larger share of R&D and innovation abroad, this study shows instead that higher wages and the cost of human capital (in line with the relative shortage of scientists and skilled workers) are a significant factor driving MNEs to invest in R&D and innovation abroad. Likewise, increasing population density, related to congestion costs and pressure on land prices and rents, has a similar influence on outward investment decisions.

The analysis finds no evidence that prior investment in production activities abroad "push" firms to follow up with R&D investments abroad. The often heard claim that the offshoring of production today will result in the offshoring of R&D and innovation tomorrow is thus not supported. The evidence only indicates that the "pull" of alternative foreign locations for investment in R&D (i.e. after the decision to offshore has been taken) is affected by whether or not they have already set up production activities in that location. Indeed, having prior manufacturing activities increases the probability of follow up R&D investment in the same location. These co-location effects between production and innovative activities tend to be more important in engineering industries as technology development is characterized by short product life cycles and continuous innovation processes.

Moreover, the offshoring of R&D and innovative activities does not hurt such activities at home. Rather, the evidence suggests that, if anything, outward investments in R&D and innovation, particularly if they concern development, design and testing, increase MNEs' innovation activities in their home city. This confirms the notion that innovation activities at home and abroad are likely to be complementary: research activities drive product & process innovations, and design & development activities drive commercialisation, market expansion and ultimately the returns to research investments. In other words, (foreign) investments in development, design and testing build on R&D efforts (at home), while conversely the market expansion effects of (foreign) development, design and testing facilitate R&D expansion and give more effective direction to R&D at home.

WHERE TO LOCATE INNOVATIVE ACTIVITIES IN GLOBAL VALUE CHAINS: DOES CO-LOCATION MATTER?

1. Introduction

The international production landscape has dramatically changed with the emergence of global value chains (GVCs) over the past decades. Production processes are increasingly fragmented and dispersed across different countries and products are accordingly "made in the world" (OECD, 2013). This unbundling trend has recently also affected R&D and innovation activities as a growing number of firms have offshored R&D and innovative activities to foreign locations during the past decade(s). R&D and innovation were among the least internationalised functions of the value chain and were traditionally considered as "core activities" to be retained close to companies' headquarters (e.g. Grossman and Helpman, 1991; Florida, 1997; Chung and Yeaple, 2008).

The internationalisation of R&D activities by multinational firms (MNEs) is driven by the continuing globalisation and the increasing geographic dispersion of knowledge and technological innovation (e.g. Belderbos et al., 2013; OECD, 2007; 2011; Cantwell, 1995). A first motivation for R&D internationalisation is to customise products, processes and technologies developed in the home country to better meet local demand (home-base exploiting R&D; Kuemmerle, 1997). Typically, such R&D and innovation activities abroad have a more adaptive character, are more demand-oriented and related to market proximity.

A second, more recent, type of R&D investment abroad is aimed at access to foreign strategic assets. These international R&D and innovation activities primarily reflect the increasing importance of supply related location factors (e.g. universities, skilled human capital, etc.) and are no longer simply incremental or adaptive. By tapping into foreign knowledge, firms aim to improve their existing assets or to acquire or create completely new technological assets (home base augmenting R&D). There is a strong rationale for geographically distributed models of R&D organisation related to the increasingly central importance of knowledge and technological capabilities for the long term competitiveness of MNEs and their ability to transfer, recombine and leverage knowledge and technologies across borders.

Despite the advantages of a distributed model of global R&D and innovation, many MNEs still exhibit an important "home bias" in their global innovative activities. Dispersed R&D and innovation also means higher - often underestimated - costs and important managerial challenges. These involve potential foregone advantages of scale and scope economies, greater appropriability concerns related to the dispersion of R&D and innovation, increased coordination costs, and difficulties and costs related to knowledge integration and transfer.

Previous OECD work has analysed the internationalisation of R&D and technology in general, and more specifically the role of MNEs as a vehicle through which this internationalisation comes about. The report on "The Internationalisation of Business R&D: evidence, impacts and implications" (OECD, 2008a) collected empirical evidence from a number of sources, discussed the motivations of R&D internationalisation by MNEs, and analysed the impacts on host countries. Follow-up work on "Attractiveness for Innovation: Location Factors for International Investment" (OECD, 2011) enlarged the scope of innovative investments beyond R&D and made a first link to the broader discussion of GVCs.

In addition to the broader trade, investment and other policy issues raised by GVCs (OECD 2013), the offshoring of R&D and innovation within GVCs poses new challenges to economic policy in OECD countries and gives rise to a number of related questions. Are outward R&D investments by MNEs a concern for the countries in which the MNEs are headquartered, and if so, are there relevant policies that can keep those investments at home? How can countries attract inward R&D investments by foreign MNEs? What are the effects of subsidies and fiscal incentives for R&D in the context of R&D internationalisation and the presence of foreign MNEs seeking to get access to local knowledge? Are there differences between research activities, with a focus on developing new technologies, on the one hand, and development activities, focusing on adapting products and processes, on the other?

The growing importance of R&D internationalisation is equally important for policy makers in emerging economies. As MNEs are leading actors and co-ordinate GVCs, attracting affiliates of foreign MNEs directly facilitates the integration of countries in GVCs; the GVC participation of several (developing) countries is indeed closely linked to the inward investment of foreign MNEs. In addition, particularly investments in innovative activities may be important for countries' GVC upgrading strategies since MNEs are among the most important vehicles through which technology is transferred across countries. By encouraging MNEs to establish local facilities, governments hope to enable the transfer of technology and to change their traditional specialisation in lower value added activities in GVCs:

Virtually all governments in emerging economies are keen to attract international investments by MNEs, particularly in high-tech, R&D and innovation activities. But despite the fact that MNEs can provide countries with access to investment, knowledge and technology, spillovers from MNEs to the host economy do not occur automatically and in some cases might not materialise at all (OECD, 2011). Empirical evidence, particularly from developing countries, has shown that local firms often lack the necessary absorptive capacity for the advanced technology and skills of MNEs (for an overview see Blomstrom and Kokko, 2003). In addition, MNEs often develop protective mechanisms to prevent their knowledge from spilling over (too easily) to local competitors, especially in countries where the enforcement of intellectual property rights (IPRs) is weak.

One particular question, that has only gained limited attention thus far, is to what extent firms prefer to co-locate innovative activities and other value chain activities such that innovative investments are likely to follow other investments? The argument often heard is that offshoring manufacturing today results in the offshoring of R&D and innovation tomorrow, but no major evidence has been developed yet. It is clear that if MNE decisions to invest in R&D and innovation abroad are shaped by earlier investments along the value chain, co-location ought to be an important issue in the policy discussion in OECD and emerging economies.

2. The internationalisation of R&D and innovation in the broader policy discussion on GVCs

This paper aims to integrate the investment and offshoring of R&D and innovation in the broader policy discussion on GVCs. In developing original evidence,[1] it discusses the location factors for international investment of R&D and innovation (in line with previous research) with a special focus on the co-location between activities along the value chain and undertaking the analysis at the level firms in global cities (instead of countries).

a) Systematic evidence on the internationalisation of R&D and innovative activities

Despite the growing policy attention, systematic evidence on the patterns of international investment in innovation has surprisingly been lacking. The evidence on the international dispersion of innovative activities is rather indirect (e.g. foreign funding of R&D, share of foreign affiliates in host countries' R&D) or based on firm surveys often for specific industries. Evidently, this limits the analysis and broader policy interpretation of the determinants and effects of the international investments and offshoring in R&D and innovation.

Instead, the analysis in this paper is based on direct systematic evidence using data on international (greenfield) investments across countries and industries during the past decade (2003-2011) as collected in the fDi Markets Database of the Financial Times (see Box 1). This database collects information on cross-border investments across different activities (production, R&D, design, testing sales, marketing and support, headquarters, etc.) across the globe. The richness of the data allows for the study of the location decisions of MNEs along the value chain in more detail. By linking this database with firm-level information and information on the host and home location, the individual decision of firms to offshore R&D and innovation can be analysed in great detail. In particular, this paper identifies which firm characteristics as well location factors (in the home as well as host country) direct firms' decisions to offshore R&D and innovation.

As previous OECD work (OECD, 2011; OECD, 2013b) has shown that innovation is much broader than only R&D, innovation activities in the empirical analysis include pure research (the R of R&D), pure development (the D), R&D, but also design and testing that are often part of development activities.[2] In particular, results will be reported respectively for all RDDT (Research, R&D, Development, Design and Testing) projects together, RRD (Research and R&D) projects and DDT (Development, Design and Testing).

Box 1. The fDi Markets Database

The fDi Markets database is probably the most comprehensive database of international investments currently available covering all countries and sectors worldwide. It is part of fDi Intelligence – a corporate division of the Financial Times ltd. The database records cross-border greenfield investment projects since 2003 and provides information on the investing company, the parent company, the source country, source state and source city, the destination country, state and city and the sector of the investing firm, and the type of activity of the investment (manufacturing, services, headquarters, R&D, etc.). For the period 2003-2011, the database includes more than 118 000 cross-border investments.

According to the Financial Times ltd., cross-border investments are identified through a wide variety of sources, including nearly 9000 media sources, project data from over 1000 industry organisations and investment agencies, and data purchased from market research and publication companies. Furthermore, each project is cross-referenced across multiple sources and more than 90% of investment projects are validated with company sources.

Greenfield investments are only recorded in the database when they lead to new physical projects or expansions of existing investments which create new jobs and capital investments; this implies that joint ventures are only included when they lead to a new physical operation. Accordingly, mergers & acquisitions and other equity investments are excluded from the database. There is no minimum size for a project to be included.

While the database includes information on the capital investments and direct jobs associated with the international projects, the empirical analysis focuses solely on the number of projects. As companies do not always release information on investment amount or job creation, the numbers on capital investments and jobs are often derived from algorithms. While acknowledging that not taking into account the size dimension of international investments may impact the results; it was felt that for the analysis undertaken in this paper the potential bias of using (rough) estimates on capital/jobs would be most likely larger.

The fDi Markets database has been widely used by international organisations (World Bank, UNCTAD, and Economist Intelligence Unit), non-governmental organisations (NGOs) and academic institutions, location consultants, MNEs and government departments involved in investment promotion and economic development. UNCTAD for example uses fDi Markets data to derive statistics for its World Investment Reports, while governments draw on the database to develop their investment promotion strategies based on up-to-date data on the actual size and growth of the greenfield FDI market. In addition, the fDi Markets database has been increasingly used by academic scholars, e.g.: Bhalla, Sodhi, & Son, 2008; Castellani, Jimenez, & Zanfei, 2013; Castellani & Pieri, 2013; Crescenzi et al., 2013; Di Minin & Zhang, 2010; D'Agostino, Laursen, & Santangelo, 2013; Kalotay & Sulstarova, 2010.

The accuracy and validity of the data has been analysed by a number of researchers. Crescenzi et al. (2013) for instance compared the investment flows of the database with information on FDI flows at the country level and reported a correlation of 0.54 over the time-span covered in their analysis (2003-2008). Furthermore, they compared the distribution of new investments across European regions with data on new investments provided by the Euromonitor database. Their comparison showed a 0.75 correlation in the number of investments reported at the NUTS-2 regional level. Castellani and Pieri (2013) also tested the accuracy and robustness of the fDi Markets database and reported high correlation coefficients (0.82 and 0.83) between the distribution of outward and inward investments projects (provided by fDi Markets) and the actual distribution of FDI flows in EU countries.

Nevertheless, the database suffers from a number of shortcomings; in the first place the exclusion of mergers and takeovers knowing that these are often used by companies in their internationalisation strategies. However, previous research has also shown that M&A are to a large extent also driven by pure financial motivations, which would without any doubt cloud the results on strategic motivations and location choice of R&D internationalisation (which is the focus of this study). Second, subtle differences in coverage over time or across countries cannot be excluded depending on the information sources available. While this is not expected to significantly impact the results of the empirical analysis, it limits somewhat the scope for comparing home and host country attractiveness for new investment projects – this should be taken into account in Section 3 discussing trends. Third, the fDi markets database does not track patterns in firms' domestic investment projects. As a result – which is a feature of all country data, European firms' cross-border investments within other European countries are tracked, while US firms' investments in the United States are not – which overall leads to a stronger representation of European firms in the database.

b) Co-location between production and innovative activities

The scarce literature on the importance of co-location effects between different activities within GVCs in the location decisions of MNEs tend to suggest that prior manufacturing or distribution investments in a region or host country increase the probability that R&D investments follow (Belderbos et al., 2014; Defever 2006; 2012; Alcacer and Delgado, 2013; Alcacer, 2006). By fragmenting and dispersing their value chains, firms optimally benefit from locational advantages across countries, but lose co-ordination advantages between activities along the value chain. Important feedback effects may exist between production and other activities while such interactions may differ across products, firms and industries (Pisano and Shih, 2009). As such, attracting production activities might be important for GVC upgrading in emerging economies, as production activities may pull more innovative activities when co-location effects are found to be important.

The reverse dynamics – losing production and then later also innovation – are hotly debated in a number of OECD countries. In general, OECD countries often specialise in the production of ideas, concepts and services, but less so in the production of physical goods. In addition to the negative employment effects, the fear is that the loss of certain manufacturing/assembly activities may result in a loss of innovative capabilities (R&D, design, etc.) in the longer-term. The loss of core manufacturing activities may set off a reaction, which will subsequently erode adjacent activities in the value chain, both upstream and downstream, including activities related to innovation and design, all of which could eventually weaken the competitiveness of OECD countries (Berger, 2013; Locke and Wellhausen, 2014).

The analysis of co-location and feedback effects between different activities along the value chains directly relates to the policy discussion in OECD countries on the future of manufacturing.[3] The argument is that high-income countries may struggle to retain innovative, R&D-based and higher value-added activities if they rely on these areas alone; one of the arguments for keeping manufacturing in OECD countries is the importance of its co-location effects with innovative activities. In addition, this project and its analysis of possible co-location effects is of relevance to the discussion of re-shoring of activities (De Backer et al., 2015). There is some evidence that companies do not always fully account for the possible feedback effects between different activities and are therefore confronted with high (hidden) costs of offshoring. In particular the protection of non-codifiable knowledge, which plays a major role in feedback and co-location effects, has been cited as a motivation for re-shoring.

c) GVCs and (sub-national) geography

The policy discussion on GVCs is typically undertaken at the level of national economies, not least because of the country focus of the available data on GVCs (for example, the OECD's TiVA database). The location of firms shows however a strong regional (*i.e.* on the subnational level) character with companies traditionally clustering in certain areas. The "economic geography" literature has formalised this location behaviour in spatial agglomeration models distinguishing between core and periphery regions dating back to Marshall's (1890) "Industrial District-argument". Companies enjoy external economies by localising close to other companies as they can take advantage from the division of labour, the exchange of input, expertise and information. Examples are respectively the existence of local labour market pool sustained by a local concentration of production, the provision of specific goods and services by specialized suppliers and knowledge externalities and knowledge spillovers between firms.

It is clear that the analysis of co-location effects cannot be undertaken at the country-level as co-ordination advantages and feedback effects typically stem from interaction over smaller distances. In discussing the importance of co-location and feedback effects, the analysis focuses on the role of major metropolitan areas, in particular "global cities". The analysis - at the firm-level - examines causes and effects of investments in R&D and innovation at the fine grained level of cities, distinguishing 57 of the world's premier "global cities" as hotspots of multinational activity (Mastercard, 2008; Taylor et al., 2009; Goerzen, Asmussen and Nielsen, 2013).

This perspective reflects that many innovations originate in large cities, which are viewed as engines of technology growth (e.g. Jacobs, 1969; Bairoch, 1991; Fujita et al. 1999). Global cities are the world's major metropolitan areas, characterized by a high degree of interconnectedness to local and global markets; a cosmopolitan cultural environment; and a strong concentration of multinational activity (e.g. Taylor, 2004; Sassen, 2001; 2006; Goerzen, Asmussen and Nielsen, 2013). Global cities host a disproportional share of skilled workers, innovative companies and high quality public and private institutions (Mastercard 2008), and attract a substantial number of cross-border RDDT investments. Notable examples of such global cities are New York, London, Paris, Shanghai, Hong Kong, China and Singapore.

The evidence and results presented in this paper are based on the project "Global R&D Locations and Decisions" commissioned by the OECD[4] to examine and analyse systematic evidence on global cross-border investments in R&D and innovation (see Box 2). The project combines an overview of key findings in the literature with original empirical research in order to provide answers to the following questions of direct relevance for policy:

a) What are the recent trends in international investments by MNEs along the value chain, particularly in innovation activities (R&D, design, testing) in terms of host and home countries; what are the flows of investment projects across different countries; do emerging economies feature more as host economies for foreign investments than as home countries; are international investment projects in production activities different from more innovative activities in GVCs; are there any industry-specific patterns present?

b) What are the determinants in the decision to engage in cross-border investments in innovative activities in GVCs? What role do so-called "push" factors play? What firm characteristics influence this decision; in particular, is the decision to offshore innovation influenced by prior foreign investments in production and other activities along the value chain?

c) What are the characteristics that attract or discourage investments in innovation when firms decide on the location of cross-border innovation investments? Which of these are amenable by government policies (e.g. the role of taxation and R&D tax credits, research strengths of universities, international interconnectedness of local industrial research, wages, and intellectual property rights protection)? What is the role of prior investments in other value chain activities of the firm in the city; what is the importance of co-location between production and innovative activities?

d) Is there evidence to suggest that MNEs investing abroad in innovative activities rely less on their home country for R&D? This relates to the broader discussion of feedback effects between activities in host and home economies? The project will not be able to completely disentangle different effects but will provide first results on the basis of information on the inventors (employees) of firms' patent.

Box 2. Project on Global R&D Locations and Decisions

* Global trends in worldwide cross-border greenfield investment projects, 2003-2011.
* Identifies more than 118 000 projects, drawing on the Financial Times' fDi Markets database.
* Close to 5 000 RDDT (Research, Development, R&D, Design and Testing) projects.
* Investment projects distinguished by industry of MNEs and value chain activity of investment (e.g. manufacturing, distribution, service&support, RDDT).
* Emphasis on co-location between RDDT and other value chain activities of the firm.
* Multivariate analysis of firm behaviour at the fine grained level of major "global" cities:
* "Push" factors: Firm and city-of-origin determinants of the decision to invest in overseas RDDT.
* "Pull" factors: Locational choices for multinational firms' cross-border RDDT investments at the city level.
* Consequences of outward RDDT: Relationship between foreign RDDT investments and firms' innovation activities in their home cities.

The following sections provide a non-technical discussion of the results of the project in direct relation to the policy discussion on R&D investment/offshoring and GVCs. The Annexes present the technical details of the multivariate analysis (models used, variables constructed and econometric results) for the interested readers.

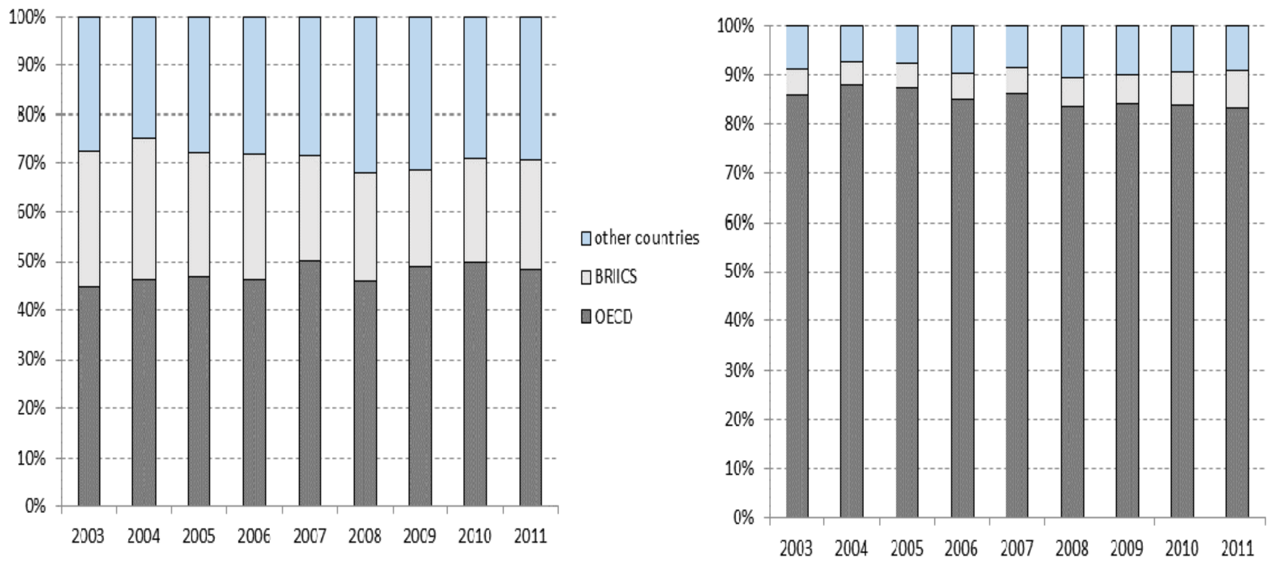
3. Major trends in international investment projects coming from the fDi Markets Database

a) OECD countries are more important as home country than as host country, but the BRIICS countries are catching up both as host and home country

OECD countries are the source or home country for the majority of cross-border investments (including all activities and all industries) in the fDi Markets databases: more than 80% of the cross-border investments are undertaken by companies with headquarters in OECD countries (Figure 1). This share has somewhat decreased over time however to the advantage of BRIICS countries which have become larger investors abroad over time. At the inward side, OECD countries attracted between 40-50% of international investment projects over the period 2003-2011, while the BRIICS economies accounted for about one-quarter of inward investments.

Figure 1. Number of investment projects, geographical distribution, 2003-2011

INWARD (HOST ECONOMIES) OUTWARD (HOME ECONOMIES)

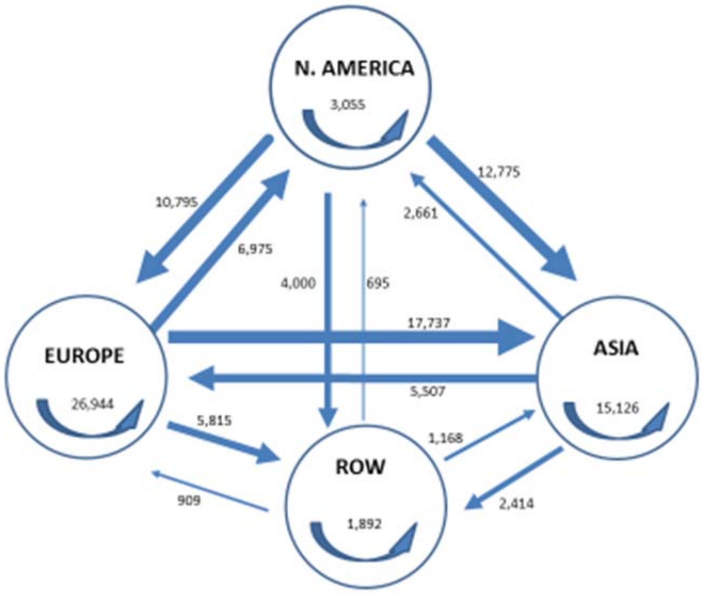


Source: Calculations based on fDi Markets database.

The limited changes for BRIICS countries are somewhat at odds with the growing importance of emerging economies reported in inward and outward FDI flows[5]. A number of reasons may explain this discrepancy: first, the investment projects included in the fDi Markets database are real investment projects that have resulted in extra-jobs, while FDI flows refer to financial flows including also mergers and acquisitions and equity investments. This may explain the smaller shares of BRIICS countries in outward investments since companies from these countries have been very active in mergers and acquisitions in developed and developing economies in recent years. Second, the data in Figure 1 relate to the number of investment projects and not to the actual capital investment like in FDI statistics.[6] Lastly, it cannot be excluded that there is some bias in the fDi Markets database in that investment in some countries are under-represented; however, this seems less of an issue for the BRIICS countries. But in general, as mentioned above, the data should be interpreted with care in assessing the attractiveness of countries for international investment.

Looking at pairs of home and host regions in the overall pattern of international investment projects shows that by far the largest number of investment projects is undertaken by European firms inside Europe (Figure 2). Intra-regional investment flows within Asia are also sizeable and growing. North America and Europe are roughly equally important as a source of inter-regional cross-border projects. Europe has been the largest investor in Asia, while there is a rough balance in North American investment projects reaching Europe and Asia. Investments from Asia to Europe are almost double the Asian investments in North America.

Figure 2. Number of investment project, supra-regional flows, 2003-2011



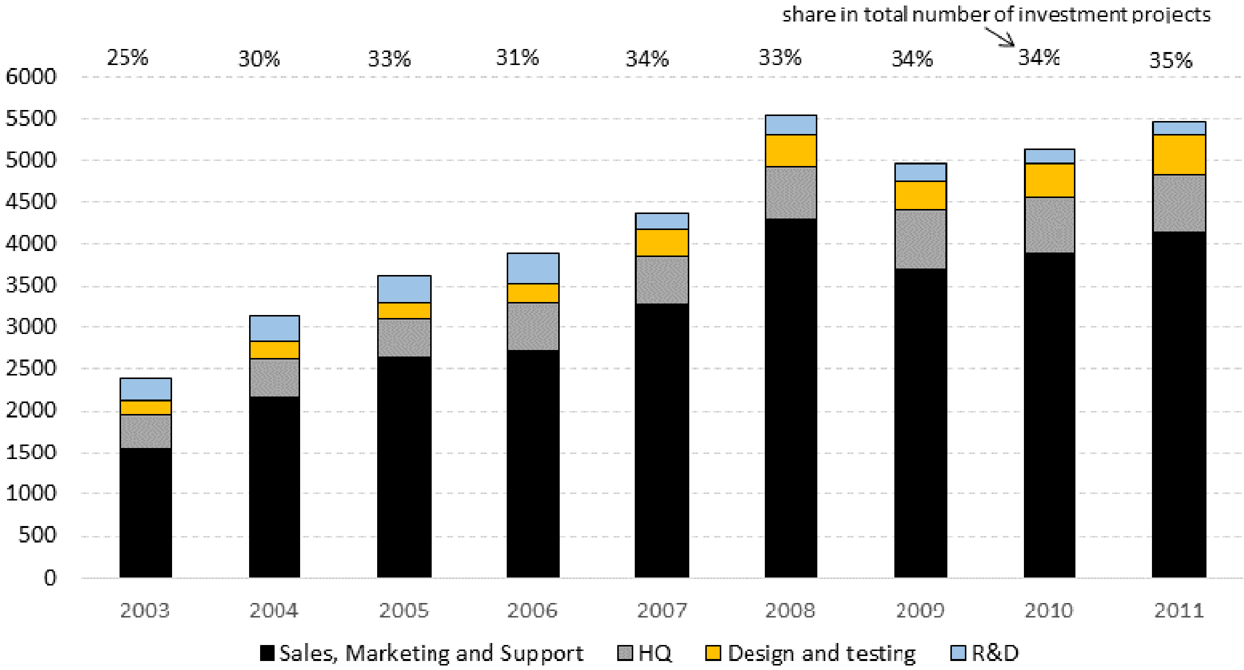
Source: Calculations based on fDi Markets database.

b) Production activities are the most internationalised, but other activities along the value chains are increasingly dispersed across countries

About two-thirds of the cross-border investment projects are production-related activities, while one third concern up- and downstream support activities (Figure 3). Sales, marketing and support represent the largest category of support activities; headquarters and innovative activities (RDDT) account for about 25% of the support activities and 8-9% of the total number of investment projects included in the fDi Markets database.

The majority of investment projects going to emerging economies concerns production activities; for example 70% of the investment projects in China, Hong Kong (China) and Brazil are production projects, while this share is 84% for Indonesia. In countries like the United States, Germany and Japan, the share of production activities is about 50-55% which is significantly lower but still represents a large number of investment projects in production activities. Headquarter and innovative activities go relatively more to OECD countries, particularly the United States and Europe.

Figure 3. Number of investment projects in up- and downstream support activities, 2003-2011

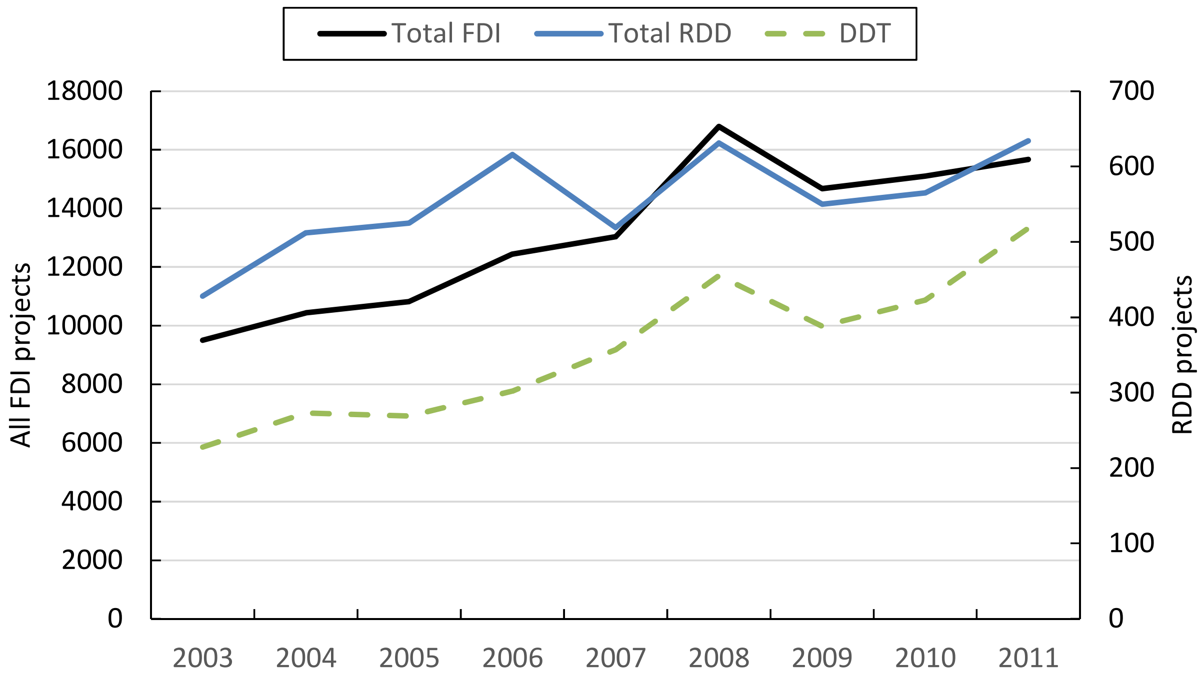


Source: Calculations based on fDi Markets database.

c) The number of cross-border RDDT projects has grown but at a smaller pace than other greenfield investments; growth in RDDT investments is concentrated in development, design and testing

The number of cross-border greenfield projects has shown a steady growth over the period 2003-2011 with a peak in 2008 before the global economic crisis (Figure 4). Growth has somewhat slowed after 2008 and investment levels by 2011 have not yet fully recovered. The overall trend in cross-border RDDT investments shows a similar pattern including a peak in 2008. The recovery has however been faster, with the number of projects reaching a high of more than 600 projects in 2011. The growth in RDDT projects in recent years is especially driven by the strong growth in Design, Development and Testing (DDT) projects, of which the number almost doubled over the period.

Figure 4. Trends in Greenfield FDI and cross-border RDDT investments

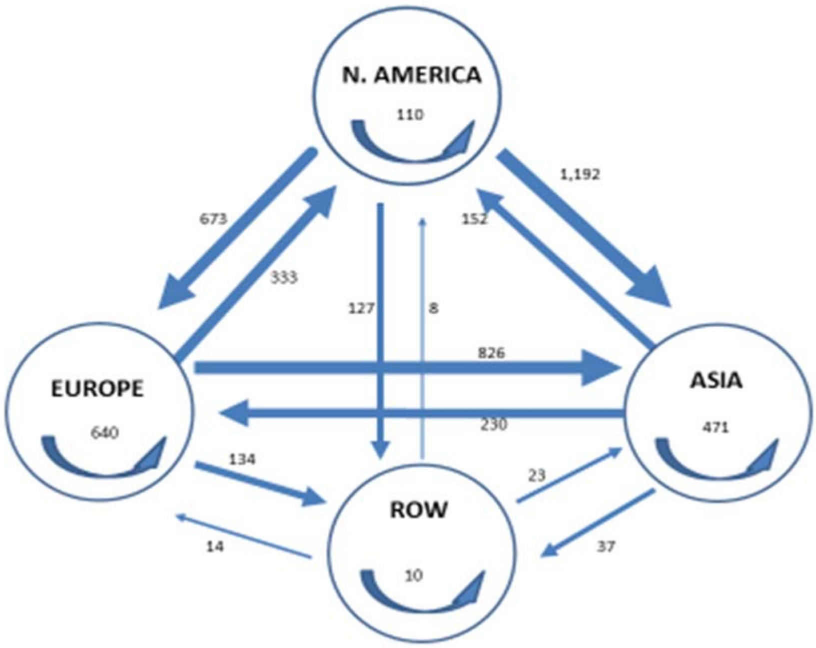


Source: Calculations based on fDi Markets database.

d) North America is the most important home region for RDDT investments while Asia is the most important destination of RDDT investments from developed economies"

The geographical pattern of RDDT investments overall resembles strikingly well the pattern of all investment projects (Figure 5): a sizeable number of intra-European RDDT projects, Asia as the most important destination for North American and European RDDT investments, and Asian RDDT investments targeting Europe more often than North America. However, a number of differences exist as North America is a more important source of international RDDT investments than Europe which most likely reflects in part its higher specialisation in technology intensive industries. The ratio of RDDT projects to total investment projects (all activities) from North America to Asia is 9.4% (roughly 1 out of 10 projects), while for Europe it is 4.6% (1 out of 20).

Figure 5. Number of RDDT investment project, supra-regional flows, 2003-2011



Source: Calculations based on fDi Markets database.

The BRIICS countries and the EU attract the largest numbers of RDDT investments (Table 1). Among the destinations that have attracted growing numbers of projects in the most recent four year period (2008-2011) relative to 2003-2006, are industrialised countries such as the United States, Germany and the UK, as well as Brazil, Mexico and South Africa.[7] Maybe surprisingly, China and India experienced a decline in inward RDDT investments in the most recent years during the considered period[8]. The decline in inward investments in emerging markets seems to be linked to the decreasing international investment by MNEs headquartered in the United States and to a lesser extent Europe, after the financial crisis.

Among source countries, the United States and the EU are responsible by far for the largest numbers of cross border RDDT projects. The share of the United States has however been declining substantially in the wake of the global financial crisis while, in contrast, growth in RDDT investments from Europe has been robust. China and India are increasingly important source countries of RDDT investments; in particular the doubling of Chinese RDDT projects abroad is striking.

On average, DDT investments make up about 65% of all RDDT projects during the period, and the share of these projects has been increasing substantially (cf. Figure 4). There seems to be no clear pattern discernible in the share of R&D and DDT investments across industrialized countries and emerging economies.

Table 1. Inward and outward RDDT by major countries and regions, 2003-2011

	Inward Investments			*Outward Investments*		
	number	growth %	DDT %	number	growth %	DDT %
EU-15 + EFTA	1321	26	60	1917	46	67
United Kingdom	321	72	60	312	24	71
Germany	198	75	74	545	45	69
France	184	-6	55	259	0	63
Spain	120	12	48	48	386	77
Italy	63	4	51	58	79	64
Other EU	221	-16	65	16	67	50
United States	438	98	67	1992	-8	63
Canada	110	48	55	109	-32	65
Mexico	55	83	80	1	-	0
Japan	91	-10	68	406	-14	65
Asian NICs	456	2	67	202	-4	67
Israel	63	48	51	27	78	70
BRICS	1713	-9	67	226	121	59
Brazil	93	163	63	5	300	80
Russia	63	-10	57	9	250	44
India	713	-28	67	84	27	50
China	824	-5	67	126	207	65
South Africa	20	467	75	2	0	50
Oceania	76	27	63	39	75	59
Total	4980	14	65	4980	14	65

Notes: Growth = % increase in investments between 2003-2006 and 2008-2011;
% DDT = share of DDT investments in total, 2003-2011;
EFTA includes Iceland, Liechtenstein, Norway, and Switzerland.
Source: Calculations based on fDi Markets database.

e) Most RDDT investments are taking place within the electronics industry

The electronics industry continues to be the most important manufacturing sector for RDDT projects, while in the services sector, the information and communication services industry comes forward as the dominant RDDT investor (Table 2). Together these industries are responsible for more than 40% of cross border RDDT projects in the fDi Markets Database. The highest growth rates of RDDT projects are observed for industries with a smaller share of RDDT investments such as the paper industry, minerals, and primary activities. RDDT projects in the services industries in general have not grown at the same pace as in manufacturing industries. A major factor here is that the positive trend in RDDT projects in the information and communication industries dropped off markedly at the start of the global financial crisis.

Table 2. Industry distribution of RDDT investments, 2003-2011

Industry sector	Number	Share %	Average growth %
Primary activities	46	0.9	69
Total manufacturing	*3519*	*70.7*	*7*
Manufacturing of food, beverages and tobacco	144	2.9	26
Manufacturing of textiles	40	0.8	38
Manufacturing of paper, wood, printing	24	0.5	117
Manufacturing of chemicals	356	7.1	17
Manufacturing of pharmaceuticals	711	14.3	3
Manufacturing of rubber and plastics	125	2.5	35
Manufacturing of minerals	43	0.9	88
Manufacturing of metals	51	1.0	29
Manufacturing of electronics	1013	20.3	3
Manufacturing of machinery	294	5.9	43
Manufacturing of transport equipment	615	12.3	7
Other Manufacturing	103	2.1	15
Construction and utilities	68	1.4	39
Total Services	*1347*	*27.0*	*4*
Wholesale, retail, transportation and storage	54	1.1	25
Information and communication services	1009	20.3	1
Financial services	24	0.5	-
Business services	191	3.8	17
Other services	69	1.4	19

Note: Growth = average yearly growth.
Source: Calculations based on fDi Markets database.

f) An important share of global RDDT investments is taking place among "global" cities; the importance of these cities for RDDT investments is particularly strong in Asia

Large metropolitan areas with strong international connections, or "global" cities, are major locations for inward and outward RDDT investment projects. About 40% of the RDDT investments are directed towards 57 of these global cities. The concentration of RDDT projects in these major cities is particularly salient in Asia (in particular Japan, China, and the ASIAN NICs) and Australia but less strong in the United States and the EU-15 (around 30%) (Table 3). While large metropolitan areas with a larger influence on the economy are the most accessible locations in Asia for RDDT investments from abroad, in Europe and the US secondary cities have also attracted RDDT investments resulting in a more equally spread of RDDT projects across a diversity of locations.

Table 3. Global cities and their importance as destinations for RDDT Investments

	Number of global cities	*Share of cities in inward RDDT*	
		2003-2006	*2008-2011*
North America	15	30	32
United States	11	27	31
EU 15 + EFTA	22	32	29
United Kingdom	2	19	19
Switzerland	2	22	33
New EU Member States	3	27	25
Japan	2	64	63
Oher Asia	10	51	44
China	2	60	54
India	2	46	34
Asian NICs	4	65	72
South America	2	8	16
Brazil	1	4	21
Russia	1	52	18
Australia	2	54	56

Note: EFTA includes Iceland, Liechtenstein, Norway and Switzerland.
Source: Calculations based on fDi Markets database.

The pattern of RDDT investments at this fine grained level of global cities shows the importance of major cities in Asia: Shanghai, Bangalore, Singapore, and Beijing are the cities that attracted more than 100 RDDT projects (Table 4). The dominance of these cities is more pronounced for DDT projects than for RRD projects. The first European city is Barcelona with 49 projects; the first US city is Boston with 25 projects. Given the focus of the database on greenfield investments can be assumed that established global cities in developed countries are somewhat under-represented in these figures as large incumbent MNEs have most likely been present with RDDT operations already present for a longer time (i.e. before 2003) in major centres.

A salient feature is that the importance of global cities as hosts of RDDT investments is almost matched by their importance as sources of RDDT investments. About 38% of RDDT investments are due to MNEs based in the 57 global cities. The set of cities responsible for RDDT investments includes major cities of industrialized countries where firms have based their headquarters, such as Paris, Tokyo, London, Munich and New York.

Table 4. Inward and Outward RDDT by major "global" city, 2003-2011

	inward	outward		inward	outward
Amsterdam	7	72	Miami	4	13
Athens	0	2	Milan	18	13
Atlanta	9	24	Montreal	19	18
Bangalore	248	11	Moscow	22	4
Bangkok	17	1	Mumbai	40	32
Barcelona	49	10	Munich	32	139
Beijing	128	12	New York	13	116
Berlin	10	8	Osaka	13	61
Boston	25	62	Paris	43	213
Brussels	17	29	Philadelphia	5	7
Budapest	25	2	Prague	16	2
Chicago	11	36	Rio de Janeiro	14	1
Copenhagen	17	10	Rome	2	5
Dallas	12	20	San Francisco	20	90
Dubai	27	7	Santiago	5	1
Dublin	39	27	Seoul	57	88
Dusseldorf	12	18	Shanghai	346	9
Edinburgh	18	2	Singapore	205	21
Frankfurt	9	2	Stockholm	17	53
Geneva	5	60	Sydney	15	5
Hamburg	11	7	Chinese Taipei	25	25
Hong Kong, China	36	19	Tokyo	43	205
Houston	7	31	Toronto	22	44
Lisbon	1	2	Vancouver	7	2
London	47	165	Vienna	15	4
Los Angeles	19	20	Warsaw	14	1
Madrid	21	7	Washington	8	12
Melbourne	23	7	Zurich	4	20
Mexico City	14	1	*Total*	*1,908*	*1,878*

Source: Calculations based on fDi Markets database.

g) International RDDT projects are not only undertaken by larger firms; also smaller and newly internationalisation firms are offshoring R&D

Finally, it is interesting to analyse if RDDT investments abroad are dominated by the group of very large MNEs, *i.e.* the argument that R&D internationalisation is only concerned with the "happy few". For a sub-sample of the RDDT projects, more detailed data are available on the investing firms which allows for the calculation of how many international RDDT projects have been set up by individual firms during the period 2003-2011. Table 5 shows that half of the number of RDDT investment projects is originating from the large number of firms that are only represented with 1 or 2 RDDT projects in the fDi Markets Database. While this is only indirect evidence, these figures suggest that also smaller and probably new

MNEs are offshoring R&D. But at the same time, close to 40 percent of the RDDT investments are due to firms that have 5 or more such investments during the period, i.e. most likely large and very global MNEs.

Table 5. Distribution of RDDT projects over firms, 2003-2011

Number of RDD projects of investing firms	1	2	3	4	5-10	10-20	> 20	all
share (%) of RDD projects	34	16	7	6	23	10	5	100
Number of firms	633	146	44	29	61	14	4	931

Note: Shares based on a subsample of projects for which firm-level data are available.
Source: Calculations based on fDi Markets database.

4. "Pull" location factors attracting cross-border RDDT investments at the city level

The attractiveness of a country or city for international investment is directly determined by the advantageous character of its location factors (OECD, 2011). While the literature on attractiveness and location factors is large and diverse, a number of factors attracting RDDT investments have been identified at the country level. These include market (size) related factors, (specialized) R&D capabilities, and the availability and costs of human capital (scientists and engineers and PhD graduates in particular). Academic research strength (the capabilities of local universities) also plays a role, in addition to corporate tax rates, RDDT incentives and sufficient protection granted to IP rights (see for example OECD, 2011).

The findings discussed hereafter follow from a detailed multivariate firm-level analysis of the choice by MNEs to invest in a specific global city. Logit (conditional and mixed) have traditionally been used to analyse the location determinants of international investments (at the country level). The analysis at the city level has the advantage that this is the level at which RDDT location decisions are actually made by MNEs. It can thus be expected that the inclusion of city level characteristics should allow for a better identification of the key drivers of these decisions.

Different models with varying number of RDDT projects and cities have been estimated dependent on the data availability for a number of variables across global cities; especially the unavailability of information on R&D tax incentives (i.e. B-index) in a number of global cities has limited the number of observations. This directly means that results can vary to an extent across models; in what follows, the most important and robust findings are discussed. The detailed econometric results are included in Annex 1 as well as details about the econometric models and the construction of the included variables.

a) Important locational factors at the city level that encourage RDDT investments are the technological strength of local universities and the international connectivity of the city

The results indicate positive effects of the cities' technological strength in the relevant sector (as indicated by patenting by local inventors) and the research strength of universities (as indicated by patent applications by local universities) on RDDT location decisions. A salient and novel finding is that additionally the international connectivity of the city matters significantly. Both the airport infrastructure and the intensity of international R&D collaboration by actors in the city at the sectoral level are found to attract RDDT investments. This suggests that MNEs search particularly for internationally connected cities to facilitate knowledge transfer across their geographically dispersed network of affiliates (Table 6).

Other factors encouraging RDDT investments are the market size and growth of cities and perceptions of political and social stability. Further on, investors prefer cities that share at least one language with the investors' home country and cities with greater English language proficiency, as these facilitate business operations. The two language factors are a natural substitute for each other: if a shared language is spoken and MNEs can communicate in their own language, English language proficiency becomes less important. Cities with higher population density, reflecting greater agglomeration and urbanisation, attract more RDDT investments, but at higher levels of density congestion charges and pressure on land prices have a discouraging effect.[9]

Table 6. Major "pull" location factors for international RDDT investments

Encouraging	Discouraging
– Strong universities	– Wage level
– Technological strength	– Corporate tax rate
– International R&D collaboration	– High population density
– Airport infrastructure	
– Market size and growth	
– Intermediate population density	
– Political stability	
– English language proficiency	
– Shared investor language	
– Fiscal R&D incentives	
– IPR protection	

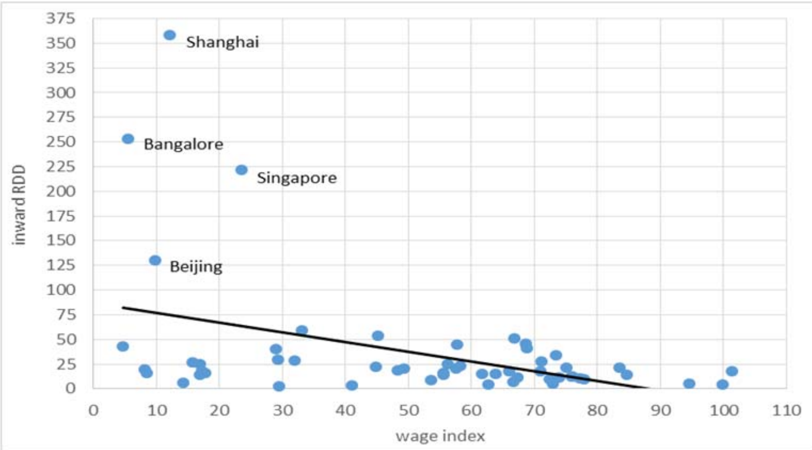
b) Some differences in locational drivers between RRD (Research and R&D) and DDT (Development, Design and Testing) projects can be observed but these are overall not very pronounced

There are relatively few differences in the location determinants of Research and R&D (RRD) versus Development, Design and Testing (DDT) investments. The results show that the location factors for both groups of projects are the same but that the size of the effects differs largely in line with theoretical predictions. In general, it is well understood that the two types of RDDT investments are driven by two core motivations: to adapt products and processes to host country conditions and help expansions in foreign markets (DDT investments) and to create new technologies and benefits from foreign R&D capabilities (R&D investments). Distinguishing between cross-border RDDT projects with a research mandate (R&D projects) and projects without such a mandate (DDT projects) in the analysis shows that R&D investments are more attracted to cities with university strength and less so to local market size, compared with DDT investments. Fiscal R&D incentives only attract R&D investments, which is most likely due to the fact that DDT investments may fall outside the scope of R&D schemes and therefore not always qualify for R&D tax relief.

c) Cost factors like the average wage levels at city level, the corporate tax rate, and fiscal R&D incentives are important drivers of RDDT investment choice among OECD countries

Measuring wages at the fine grained level of cities, one of the most consistent findings is that higher wage levels (of skilled employees) discourage RDDT investments. Figure 6 illustrates the negative relationship between the average wage level of cities over the period relative to Zurich and the number of RDDT projects a city attracts. The four higher points in the figure are for Shanghai, Bangalore, Singapore and Beijing. The results of the more detailed multivariate analysis of the study suggests an elasticity of RDDT investments with respect to wage levels of about -0.9 meaning that a 10% rise in wages decreases the probability that a city is chosen for RDDT investments by 9%.[10] OECD (2011) reported that the literature remains ambiguous the importance of labour costs for R&D personnel - with several studies reporting contrasting results- although evidence points to a growing importance particularly in emerging economies.

Figure 6. The association between wages (of skilled employees) and inward RDDT projects across global cities



Note: The wage index is relative to Zurich (100).

Previous studies have demonstrated that taxation plays a role in the location of R&D (and innovation) as the corporate tax rate is observed to discourage R&D investments [see for example Bloom et al. (2002) and Griffith et al. (2011) while R&D tax incentives increase the attractiveness of host countries (for example: Belderbos and Somers (2014)]. More in general - taking into account different forms of location-based incentives (including taxation but also more direct support like subsidies) - OECD (2011) reported that these government support may play some role especially in the final stages of the decision-making process on foreign R&D investments. But the literature also clearly showed that government support cannot compensate for the negative effect of other (more) important factors in the business environment (OECD, 2011).

The results in this paper show a discouraging effect of the corporate tax rate and an encouraging effect of fiscal incentives for a subset of cities for which broader tax information (including fiscal incentives) is available[11]. The results indicate that in line with previous research, the tax burden can shift location choices of MNEs significantly (Figures 7 and 8). Estimated elasticities from the detailed analysis are -0.8 for the corporate tax rate and 0.9 for fiscal R&D incentives. This suggests that a 10 percent rise in corporate tax rate decreases the probability that a city is chosen for RDDT investments by 8%, while a 10% rise in the R&D tax incentives increases the probability by 9%.[12]

Figure 7. The association between the corporate tax rate and inward RDDT projects across global cities

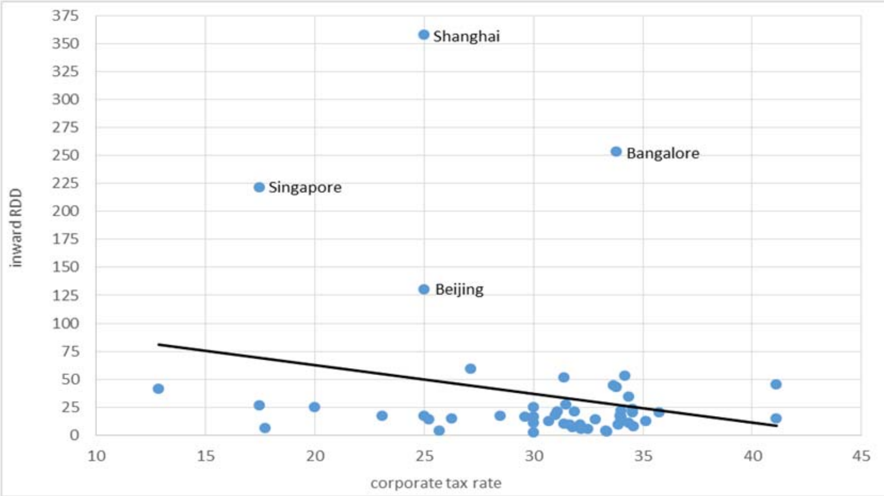
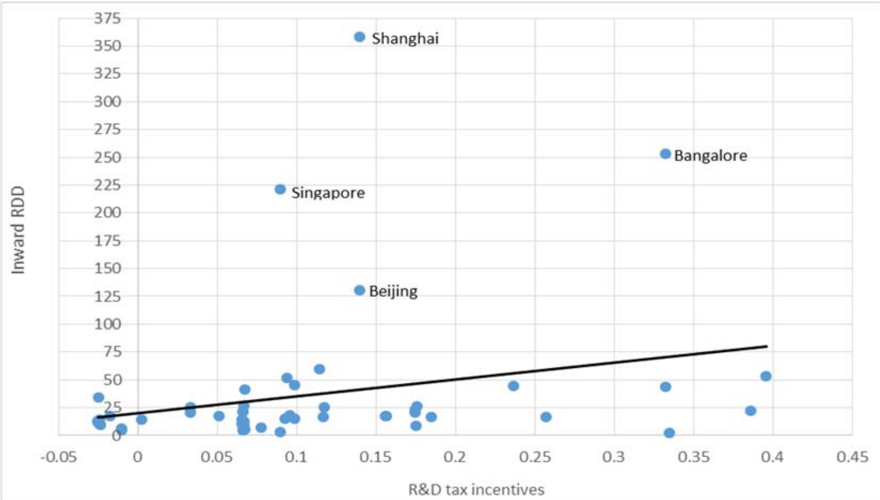


Figure 8. The association between fiscal R&D incentives and inward RDDT projects across cities



Note: fiscal incentives is 1 minus the B-index and is an indicator of the reduction in the tax burden specifically for R&D expenditures

d) The available evidence points to an increased competition between OECD countries to attract (inward) RDDT investments.

Corporate tax rates have been reduced while fiscal incentives increased in OECD countries and elsewhere over the period 2002-2011 (Table 7). Average corporate tax rates have fallen steadily from 25.4% to 21.4% in OECD countries, while the rate of fiscal incentives for RDDT investments increased substantially in proportional terms, from less than 0.08 to 0.13. In the non-OECD countries included in the analysis, corporate tax rates also declined but from a higher level, while fiscal incentives rose to a high average rate of 0.192. In combination with the reported effects of taxes and fiscal incentives on RDDT location decisions, these trends suggest that the competition to attract or maintain RDDT has increased between countries and cities (see also OECD, 2011).

Table 7. Trends in the corporate tax rate and fiscal incentives for RDDT, 2002-2011

Corporate tax rate	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	average growth (%)
OECD	25.4	25.2	25.3	25.1	23.7	23.7	22.5	22.5	21.5	21.4	-2.1
NON-OECD	33.0	32.0	31.0	29.6	29.3	28.8	27.3	27.1	26.8	26.6	-2.7
1- B index											
OECD	0.077	0.089	0.088	0.114	0.119	0.122	0.125	0.127	0.128	0.130	7.3
NON-OECD							0.148	0.164	0.176	0.192	3.4

Note: averages are for the 32 countries included in the empirical analysis.

5. "Push" location factors driving outward RDDT Investments at the city level

Previous research on the role of the specific home-country or home-region characteristics on the propensity of firms to invest in R&D abroad is rather limited. A factor that has been highlighted as a potential driver of outward RDDT is the lack of skilled scientists and engineers at home (Lewin et al., 2009). In contrast, the embeddedness and co-specialisation of RDDT operations of the MNE and the home economy has been found to discourage firms to conduct a larger share of RDDT abroad (Belderbos et al., 2013).

The model used in this analysis is a hazard model which takes into account the time of RDDT investments as most firms that invest abroad in RDDT have only one or a few investments. The analysis also includes a control group of firms that had no RDDT investment abroad during the considered time period.[13] Again, in what follows, the most important and robust findings are reported on; Annex 2 provides detailed information on the econometric model, included variables and presents the detailed econometric results.

a) There are few systematic drivers at the city level leading to increased outward RDDT investments

The multivariate analysis has identified only a limited set of city drivers robustly affecting firms' decisions to engage in cross border RDDT (Table 8). Instead, firm level characteristics are found to dominate the decision to invest in RDDT abroad: RDDT investments are more likely the larger the firm and the greater the scale of its innovation activities (i.e. the larger the firm's patent holdings). There is (weak) evidence that the international connectedness of the city (through international R&D collaboration patterns) is associated with more outward RDDT investment. As international connectivity is also strongly related to inward RDDT, it is clearly associated with two-way RDDT flows and most likely with further integration of the city in the international RDDT networks of firms.

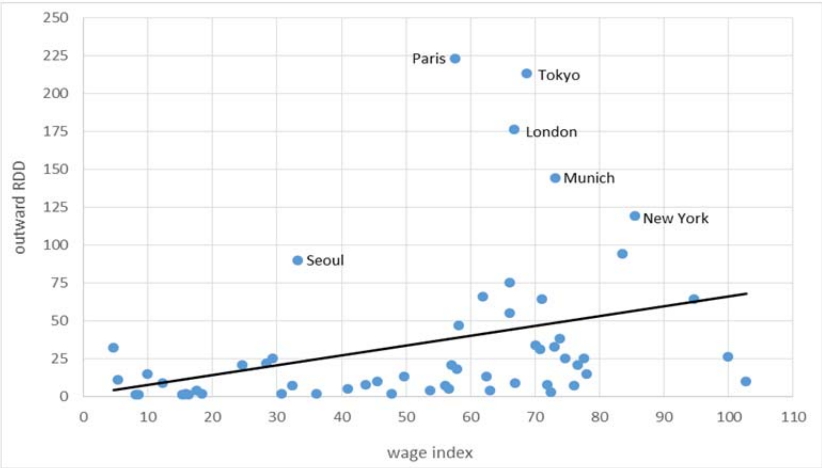
Table 8. Significant Drivers of RDDT Locations at the City level

City	Firm
– Population density	– Firm size
– Wage level	– Size of innovation activities
– International R&D collaboration	

b) The most salient city-level factors increasing the probability that firms invest in RDDT abroad are the wage level in the city and its population density

A robust finding is that firms are more likely to invest in RDDT projects abroad the higher the wage levels in their city of origin and the higher the population density in the city. Hence, it appears that relevant city of origin factors primarily relate to the cost of conducting RDDT: the cost of human capital (in line with the relative shortage of scientists and skilled workers, and possible congestion costs related to density). Figure 9 shows a clear correlation between the number of outward RDDT project of a city and its average wage level; the estimates of the multivariate analysis suggest a relatively high elasticity between 1.5 and 1.8.

Figure 9. The association between wages and outward RDDT projects across cities



Note: the wage index is relative to Zurich (100).

6. Co-location of RDDT and other activities along the value chain

The internationalisation of R&D and other innovative activities along the value chain has been argued to follow firms' prior internationalisation of manufacturing and sales activities. Yet these inter-relationships have not received much systematic attention in earlier studies nor have been supported by large evidence. On the one hand, global integration has spurred firms to locate different value-chain activities there were the location factors are the most advantageous; this has overall resulted in the geographic dispersion of activities along the value chain. Given however that dispersion typically increases coordination, integration and transport and travel costs; important benefits to co-location may exist, hence rendering location decisions for activities in the value chain dependent on each other (Alcácer, 2006). For example, MNEs often try to address coordination problems by pursuing consolidation or co-location of several value-creation activities at key locations.

In order to assess the importance of co-location patterns of RDDT investments, information on prior investments at the city level was included in both the locational choice model of the so called "pull" factors for inward RDDT (see section 3), and in the model identifying the "push" factors of outward RDDT (see section 4). As such, the location choice model analyses whether firms' prior investments in a host city influence its subsequent RDDT location decision, while the model on outward RDDT investigates whether the probability that a firm engages in outward RDDT is related to the firm's prior outward investments (in any host country or city).

Details about the construction of the variables on prior investments are presented in Annex 3, as well as the detailed econometric results for both sets of models. The inclusion of the variables on prior investments did not change fundamentally the results on push and pull factors reported above, supporting the validity and robustness of the results.

a) Firms have a tendency to locate RDDT activities in cities in which they have previously invested in core activities (manufacturing or services)"

Table 9 illustrates the general patterns of co-location for RDDT abroad in the fDi Markets Database. It lists the percentage shares of RDDT projects in cities that follow, or do not follow, prior investments along the value chain in the same city in a 5 year window[14]. On average 67% of RDDT investments did not follow previous investments of the firm in the city in the previous five years. Investments in RDDT are clearly most frequent when prior investments are core activities (manufacturing or services) or if the firm already has invested in the city in RDDT before. RDDT investments follow prior investments in headquarter activities and down- or upstream investments (distribution, marketing, logistics) less frequently.

Table 9. Co-location: RDDT investments following previous investment project by the firm at the global city level

	all countries	developing	developed
No prior FDI	67	60	72
Prior FDI	33	40	28
Prior core investment	15	20	11
Prior RDD	18	25	14
Prior HQ	5	6	5
Prior Up/downstream	8	11	5

Table 9 also shows that co-location patterns differ somewhat between global cities located in developed countries and developing countries. Co-location patterns tend to be more pronounced in developing countries with 40% of the RDDT investments following earlier investments by the investing firms; co-location in developed countries seems somewhat smaller with only 28% of RDDT investments following previous value chain investments. RDDT investments in developing countries are more likely to follow RDDT investments (25 versus 14% in developed economies), core business investments (20 versus 11%), downstream or upstream investments (11 versus 5%), and, marginally, HQ investments (6 versus 5).

One explanation for these differences is that foreign investors are less well-established in, and familiar with these countries, such that market growth potential - particularly in Asian emerging economies - attracts multiple rounds of investments. A second factor is the larger relative importance in developing countries of the large and internationally connected cities. Because of their status as international business hub, these global cities' makes co-location of activities within the confines of the cities more attractive.

The multivariate analysis taking into account other pull and push factors, confirms a number of these observations. The probability that a firm chooses a specific city for its RDDT investment projects is indeed significantly higher if that firm has invested in core activities (manufacturing for a manufacturing firm, services for a services provider) in that city during the previous five year period. So, when choosing a location for a new RDDT project abroad, firms will often look at global cities where they have already set up production activities. There is also some (but less robust) evidence that prior investment in headquarters and RDDT activities might "pull" new investments to the global city in question. Perhaps surprisingly, no differences in co-location patterns for RRD (Research and R&D) and DDT (Development, Design and

Testing) were observed, meaning that more innovative activities closer to the market do not co-locate more with production activities than innovative activities with a research mandate.

When looking at this from the reverse angle (outward instead of inward), only prior RDDT investments are found to be a precursor of new RDDT investments abroad. Foreign investment in other activities along the value chain including production activities are not found to play a role. Together, this means that firms that have invested in RDDT abroad in the past 5 years are more likely to do so again. It also implies that, at least in the context of this study, there is no evidence that prior investments in core activities abroad "push" firms soon to follow up with RDDT investments.

b) Co-location forces tend to be more salient in engineering intensive industries, but drivers of co-location may often be firm-specific rather than industry-specific.

Co-location patterns are likely to differ across firms and industries when taking into account a) differences related to the engineering intensity of industries, and b) differences related to the potential separability of RDDT functions. Engineering industries are characterised by close interaction between production and RDDT activities, as technology development is directed by short product life cycles and continuous process. Using information on the number of engineers employed (as a percentage of total industry employment)[15], engineering intensive industries are especially found in manufacturing; examples are machinery industries, semiconductors, aircraft, and measurement apparatus, but also architectural services in the services sector.

RDDT separability is generally determined as a function of the role of software development and the science-based nature of R&D. According to Pisano and Shih (2012) in industries in which design processes can be separated quite easily, such as in industries where design and development focuses on software design, co-location advantages are reduced. Similarly, basic research activities in science based industries, primarily in the biopharmaceutical industries, tend to have a closer interaction with science than with manufacturing activities. These RDDT activities focus less directly on commercialisation and applicability and there is less need to coordinate on an intensive basis with marketing and manufacturing. The sectors with potentially separable design and RDDT functions include software industries, telecommunication based industries, consumer products, professional services, and basic research oriented industries.

The evidence on industry-specific patterns overall coming out of the multivariate analysis shows different co-location effects for engineering intensive industries and R&D separable industries in line with theoretical hypotheses. In the analysis of the decision where to locate RDDT activities, co-location effects with core activities are indeed significantly stronger in engineering intensive industries, while co-location with core activities is significantly weaker in RDDT separable industries. In engineering intensive industries co-location with prior RDDT is weaker, pointing at a pattern of smaller scale RDDT operations close to the firms' core establishments in manufacturing or services.

While the analysis above has shown that co-location is important (for certain activities along the value chains) and differs across industries, it should be stressed that co-location advantages are at the same time very heterogeneous across firms as they are basically a function of firm-specific organisation factors. The advantages of coordination and co-location of production and RDDT are a more complex function of the maturity of technologies, modularity of production and the presence of standardized designs, the complexity of production processes related to firms' technology strategies, and the separability of the design function (Pisano and Shih, 2012).

7. Outward RDDT projects and Innovation at Home

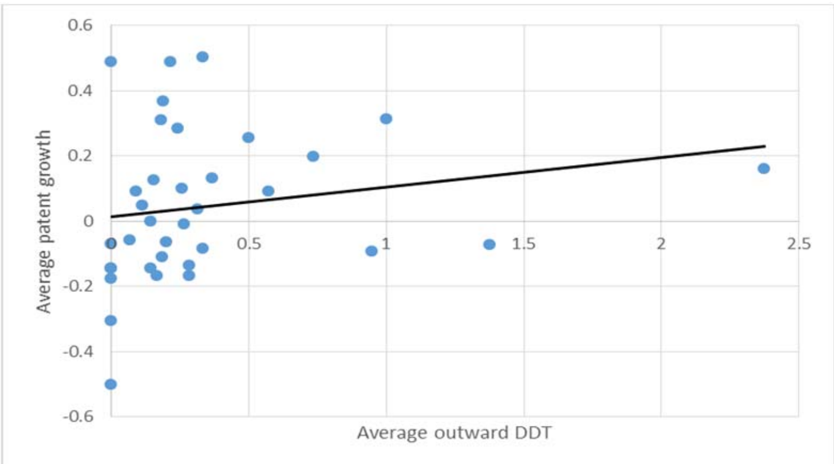
Although the location literature has indicated that regions and countries compete for foreign RDDT projects, the scarce literature on the effects of outward RDDT on the home region of MNEs has not found a substitution effect but has suggested rather complementary effects between foreign and domestic RDDT. Complementarity can stem from broader access to diverse knowledge creation and recombination, and from the positive interaction between research activities (driving product & process innovations) and design & development activities (driving commercialisation, market expansion and the returns to research investments).

Empirical analysis in this project has tried to (help) address this question by using the data on RDDT projects abroad in the fDi Markets Database. Changes in home RDDT activities have been examined through firms' patenting activities in the city in which the firms have their headquarters. It should be stressed that this analysis offers only a first assessment of potential substitution versus complementary effects[16] and more extensive analysis is needed on this important policy issue. Nevertheless, the results help to qualify some of the claims that foreign activities also in RDDT come at the expense of activities at home. Annex 4 provides more detail on the model, variables and econometric results.

Firms' innovation activities at home do not show a negative association with their outward RDDT investments. The relationship between outward investments in development, design and testing and innovation activity rather is positive

The analysis overall does not identify any negative relationship between prior outward RRD at the one side and investment firms' innovation activities in the city in which they are headquartered and operate R&D activities at the other side. Instead, it identifies a positive relationship between prior investments abroad in Development, Design and Testing, and patent growth in the home city. This finding suggests a complementary role of development activities abroad and research activities at home, as overseas expansion and market adaptation builds on the results of research at home and enhances the expected returns on such research activities. Figure 10 illustrates the positive association between the firms' outward DDT investments and their joint innovation growth in the home city**.**

Figure 10. The association between outward RDDT investments and innovation activities at home



8. What does this mean for policy?

In developing and analysing systematic evidence on global cross-border investments in Research and Development, and Design and Testing activities (together referred to as “RDDT investments”), this project aims to address a set of policy questions focusing on the offshoring of R&D and innovation within GVCs.

a) The evidence suggests that, if anything, outward RDDT investments increase MNEs’ innovation activities in their home city

The pattern of new cross-border RDDT investment projects during 2003-2011 shows that a substantial share of RDDT projects is destined for Asian markets, with internationally connected “global” (internationally connected) cities such as Shanghai, Beijing, Bangalore and Singapore acting as major hosts. However, partially as a result of the global financial crisis, these locations showed a decline in inward RDDT investments in the most recent years under investigation (2008-2011). In contrast, major industrialized economies such as the United States, Germany and the UK have received a growing number of RDDT investments in recent years. At the same time, India and China have become increasingly important as source countries of RDDT investments. Hence, there appears to be an emerging pattern in global RDDT investments towards a greater balance in outward and inward RDDT in OECD countries.

A key characteristic of cross-border RDDT investments is that the majority of these projects concern development, design and testing, i.e. activities that benefit from close proximity to MNEs’ major markets. The evidence suggests that, if anything, outward RDDT investments, if they concern development, design and testing (DTT), increase MNEs’ innovation activities in their home city. The offshoring of R&D and innovative activities does not necessarily hurt activities at home, rather the opposite. This conforms to the notion that R&D and DDT investments are likely to be complementary: research activities drive product & process innovations, and design & development activities drive commercialisation, market expansion and ultimately the returns to research investments. In other words, DDT investments build on the results of R&D efforts, while the market expansion effects of DDT facilitate R&D expansion and give more effective directions to R&D.

b) International connectivity and university research play important roles in the attractiveness of cities for inward RDDT investments.

Analysis at the level of global cities identifies important locational drivers of cross-border RDDT decisions by MNEs. Beyond factors highlighted in previous studies, the evidence suggests the importance of international connectivity of locations, which facilitates MNEs’ operations and knowledge flows within multinational networks. In this study, such connectivity is reflected in the availability of airport infrastructure and is also indicated by cross-border R&D collaboration by inventors in the city. Another salient aspect observed is the positive role of local universities’ relevant research strengths - as indicated by universities’ applied research leading to university patenting – if university research is in domains relevant to the sector of the investing MNCs. These findings imply positive effects of policy initiatives focusing on international R&D collaboration, infrastructure for global travel and transactions, and support for entrepreneurial universities.

c) The differences in the role of locational drivers between R&D and DDT investments are not very pronounced.

There are relatively few differences in the location determinants of R&D projects versus Design, Development and Testing (DDT) investments. Differences are only a matter of degree. Two core motivations of R&D internationalisation prevail: to adapt products and processes to host country conditions and help expansions in foreign markets (DDT investments) and to create new technologies and benefits from foreign R&D capabilities (R&D investments). The evidence confirms that R&D investments, as compared with DDT investments, are to a greater extent attracted to cities with strong universities but less so to local market size. Fiscal R&D incentives only attract R&D investments, which is most likely due to the fact that DDT investments may fall outside the scope of R&D schemes and may therefore not always qualify for R&D tax relief.

d) Cost factors matter for inward and outward RDDT decisions.

Cost factors are often regarded as secondary considerations in international RDDT decisions. The evidence in this paper, however, suggests that cost factors do play an important role in MNEs' location decisions. This is particularly so because an increasing number of potential RDDT locations satisfy key conditions concerning basic infrastructure, bringing cost factors to the forefront of attention. Hence, the wage level (for skilled employees) in cities is an important negative factor in the ability of locations - be it countries or cities - to attract RDDT investments. Moreover, higher wages are a significant factor driving MNEs to invest in RDDT abroad. Increasing population density, related to congestion costs and pressure on land prices and rents, has a similar influence on RDDT locations and outward RDDT investments decisions.

e) The available evidence points at increased (fiscal) competition between OECD countries to attract (inward) RDDT investments.

Taxation related to RDDT investments is observed to be another important cost factor affecting RDDT location decisions. Among major cities in OECD countries - locations satisfying key conditions concerning basic infrastructure - corporate tax rates reduce inward RDDT investments while fiscal R&D incentives encourage these. In addition, there has been a clear pattern in OECD countries and elsewhere (almost without exception) to reduce corporate tax rates and increase fiscal incentives for RDDT investments. These two observations clearly suggest that OECD countries are increasingly engaged in fiscal competition to attract RDDT investments. The consequence may be a continuous rise in the costs of attracting RDDT investments without a corresponding increase in RDDT investments in the OECD area. Coordination between countries and guidelines on fiscal incentives should aim at increasing policy efficiency and take into account the negative effects of such policy competition.

f) Firms have a strong tendency to co-locate RDDT activities with existing manufacturing activities within GVCs; this pattern is more pronounced in engineering intensive industries.

With the increasing globalisation of MNEs' value chains and given the advantages of spatial co-location of RDDT activities with other value chain activities within GVCs, there is a distinct relationship between RDDT decisions and other value chain investments by MNEs. Although about two thirds of cross-border RDDT projects are not associated with prior value chain investments (in a five year period) by the MNE, there is robust evidence that prior manufacturing activities increase the probability of follow up RDDT investment in the same location. Prior RDDT investments in a city are also often a precursor of new RDDT investments in that city.

In engineering industries there tends to be a closer interaction between manufacturing and RDDT, as technology development is characterized by short product life cycles and continuous innovation processes. The evidence indeed suggests that co-location forces between manufacturing and RDDT activities are significantly stronger in industries with higher engineering intensity. The implication of such co-location tendencies is that policies to attract manufacturing investments indirectly influence the incentives for RDDT investments.

Notwithstanding these positive co-location effects, the analysis finds no evidence that prior investments in production activities abroad “push” firms to follow up with R&D investments. The claim that the offshoring of production today will result in the offshoring of R&D and innovation tomorrow is not supported. The evidence only indicates that when firms decide about the location of R&D abroad (i.e. after the decision to offshore has been taken), they tend to prefer locations where they have already set up production activities.

g) Incentives for RDDT investments by MNEs will encourage international knowledge flows, and the benefits of policy induced RDDT are likely to be spread internationally.

Although the current project did not specifically analyse knowledge flows within MNEs, a distinct possibility is that incentive-driven inward RDDT investments in industrialised countries by emerging market MNEs draw on the local innovation base, with an important part of the created and sourced knowledge feeding into RDDT and manufacturing activities in their home operations. In this regard, emerging market MNEs increasingly resemble MNEs based in industrialized countries, for which this pattern of effective overseas knowledge sourcing has been confirmed in a broad range of studies.

Policy makers should be aware that cross-border knowledge transfers combined with a global cost optimisation of firms’ RDDT activities are essential factors in MNEs’ competitiveness and growth prospects. In this sense, national or subnational policies to provide incentives to MNEs’ RDDT investments, both foreign and domestic MNEs, are likely to generate knowledge flows and productivity effects abroad as well as domestically. The more interconnected the global economy becomes, the higher the risk of leakage effects from domestic policies.

At the same time - despite the advantages of a distributed model of global RDDT - many MNEs still exhibit an important “home bias” in their global RDDT operations. This is due to the often underestimated costs and managerial challenges inherent to international RDDT, involving potential foregone advantages of scale and scope economies, greater appropriability concerns related to RDDT dispersion, increased coordination costs, and difficulties and costs related to knowledge integration and transfer across borders and organisational units.

NOTES

1 Previous OECD work on R&D internationalisation (OECD 2008 and 2011) brought together the existing evidence, without however developing own empirical analysis.

2 The fDI database distinguishes between R&D at the one side and Development, Design and Testing at the other side; given that both categories shared "development" activities, additional work was undertaken to come to cleaner categories. Based on a careful reading of the articles accompanying the project in the database, the research and development were split where possible (in 80% of the R&D cases). Also because some of the individual groupings were too small in number, the classification RDDT, RRD and DDT were used in the empirical analysis.

3 A similar discussion is about "Making things instead of ideas" in a number of countries.

4 This project was undertaken by Prof. R. Belderbos, Prof. L. Sleuwaegen and P. Somers (University of Leuven) in co-operation with the OECD Secretariat. The academics are experts in international business, international investment and MNE strategy and have years of experience in working with the fDi Markets Database.

5 Nevertheless, the number of inward investments in BRIICS countries has increased with 34.2% during the period 2003-2011: BRIICS countries have attracted a growing number of international investments projects with a particular strong performance for Brazil. An exception is Russia which received less inward investment in 2011 than in 2003.

6 BRIICS countries show larger shares in inward investments when analysed in terms of capital investments instead of the number of projects. But as mentioned above, it is not always clear how data on capital investments have been estimated within the fDi Markets database; further on, a couple of very large investments projects may overstate the importance of host/home economies for greenfield investments, hence the proposal to use the number of projects in the proposed analysis.

7 Although the number of RDD projects in the African continent in general remains low.

8 Several reasons may explain this evolution including the lower growth prospects of emerging economies.

9 In models including the B-index, some of the effects are less strong and even become non-significant (e.g. university strength, political stability, English language proficiency and language similarity); this is due to the smaller number and the more similar characteristics of the global cities included (see Annex 1). In later models analysing co-location effects however, the reported - positive - effects are again observed showing the robustness of the results.

10 When including the corporate tax rate and the B-index, this elasticity decreases to -0.6.

11 This subset of cities is located in OECD countries, India, and China; overall, global cities with a strong general attractiveness often displaying relatively similar location factors in terms of infrastructure, etc.

12 Because of the negative correlation between the corporate tax rate and R&D tax incentives (implying that countries with higher tax rates are also more likely to provide stronger compensating R&D tax benefits),

the models not including the B-index show non-consistent results for the corporate tax rate. The elasticities reported here relate to the models including both variables (but hence for a smaller number of global cities given the non-availability of the B-index).

13 Annex 2 provides more information on the choice of the hazard model above a probit/logit model, as well as the formation of the control groups.

14 Prior investments have been determined as projects in the fDi Markets Database undertaken during the period 2003-2007; co-location was then established with follow-up investments in the fDi Markets Database during the period 2008-2011. This of course does not take into account possible prior investments by the firm in the city before 2003; an alternative of using the ORBIS database for determining prior investments (also allowing to better taken into account the time dimension of investments) has been explored but was decided against because of other major shortcomings (see Annex 3 for more details).

15 Engineering intensities above the median are categorized as sectors with high engineering intensity and industries below as low engineering intensive (source: US data on engineers employed across industries).

16 The analysis focuses on the relationship for (only) a sample of 181 firms based in 35 global cities and covers the period 2004-2011. Further on, effects on innovative activities at home are assessed (only) in terms of patents.

REFERENCES

Abramovsky, L., Griffith, R., and H. Miller (2008), "UK technology performance, multinational firms and the location of innovative activity", *Mimeograph*, University College London, London.

Ahuja, G. and R. Katila (2001), "Technological acquisitions and the innovation performance of acquiring firms: A longitudinal study", *Strategic Management Journal*, 22(3): 197-220.

Ahuja, G. and R. Katila (2004), "Where do resources come from? The role of idiosyncratic situations", *Strategic Management Journal*, 25(8-9): 887-907.

Alcácer, J. (2006), "Location choices across the value chain: How activity and capability influence co-location", *Management Science*, 52(10): 1457-1471.

Alcacer, J. and W. Chung (2007), "Location strategies and knowledge spillovers", *Management Science*, 53(5): 760-776.

Alcacer, J. and M. Delgado (2013), "Spatial organization of firms and location choices through the value chain", *Harvard Business School*: 13-025.

Allred, B. B. and W.G. Park (2007), "Patent rights and innovative activity: evidence from national and firm-level data", *Journal of International Business Studies*, 38(6): 878-900.

Almeida, P., Song, J. and R.M. Grant (2002), "Are firms superior to alliances and markets? An empirical test of cross-border knowledge building", *Organization Science*, 13(2): 147-161.

Ambos, B. (2005), "Foreign direct investment in industrial research and development: A study of German MNCs", *Research Policy*, 34(4): 395-410.

Arora, A., Belenzon, S. and L.A. Rios (2011), The organization of R&D in American corporations: the determinants and consequences of decentralization, *National Bureau of Economic Research workign Paper, No. 17013*.

Asakawa, K. (2007), "Metanational learning in TFT-LCD industry: an organizing framework", *RIETI Discussion Article*.

Bandick, R., Görg, H., and P. Karpaty, P. (2014), "Foreign acquisitions, domestic multinationals, and R&D", *The Scandinavian Journal of Economics*, 116(4): 1091-1115.

Bas, C. L. and C. Sierra (2002), "Location versus home country advantages' in R&D activities: some further results on multinationals' locational strategies", *Research Policy*, 31(4): 589-609.

Basile, R., Castellani, D. and A. Zanfei (2008), "Location choices of multinational firms in Europe: The role of EU cohesion policy", *Journal of International Economics*, 74(2): 328-340.

Belderbos, R. (2003), “Entry mode, organizational learning, and R&D in foreign affiliates: Evidence from Japanese firms”, *Strategic Management Journal*, 24(3): 235-259.

Belderbos, R. (2001), “Overseas innovations by Japanese firms: an analysis of patent and subsidiary data” *Research Policy*, 30(2): 313-332.

Belderbos, R., Fukao, K., and H.U. Kwon (2006), “Intellectual property rights protection and the location of research and development activities by multinational firms”, *Hi-Stat HSH Discussion Paper Series*, 167.

Belderbos, R., Ito, B. and R. Wakasugi (2008), “Intra-firm technology transfer and R&D in foreign affiliates: Substitutes or complements? Evidence from Japanese multinational firms”, *Journal of the Japanese and international Economies*, 22(3): 310-319.

Belderbos, R., Leten, B. and S. Suzuki (2013), “How global is R&D? Firm-level determinants of home-country bias in R&D”, *Journal of international business studies*, 44(8): 765-786.

Belderbos, R., Leten, B. and S. Suzuki (2010), “International R&D and Firm Performance: A Contingency Approach”, *30th Strategic Management Society Conference*. Rome, Italy.

Belderbos, R., Lokshin, B. and B. Sadowski (2015), “The returns to foreign R&D”, *Journal of International Business Studies*, 46: 491-504.

Belderbos, R., Lokshin, B., Boone I. and J. Jacob. (2014), “Diversity of Top Management Teams and the Effectiveness of Global Knowledge Sourcing: Nationality and International Work Experience”, paper presented at *the 2014 SMS Special Conference on Startup and Restart Strategies*, Tel Aviv, Israel.

Belderbos, R., Lykogianni, E., and R. Veugelers (2008), “Strategic R&D location in European manufacturing industries”, *Review of World Economics*, 144(2): 183-206.

Belderbos, R. and D. Somers. (2015), “Do technology leaders deter inward R&D investments? Evidence from regional R&D location decisions in Europe”, *Regional Studies*: 1-17.

Belderbos, R., Tong, T. W. and S. Wu, S. (2014), “Multinationality and downside risk: The roles of option portfolio and organization”, *Strategic Management Journal*, *35*(1), 88-106.

Belderbos, R., Van Roy, V., Leten, B. and B. Thijs (2014), “Academic research strengths and multinational firms’ foreign R&D location decisions: evidence from R&D investments in European regions”, *Environment and Planning A*, 46(4): 920-942.

Berry, H. (2014), “Global integration and innovation: Multicountry knowledge generation within MNCs”, *Strategic Management Journal*, 35(6): 869-890.

Berry, H. (2006), “Leaders, laggards, and the pursuit of foreign knowledge”, *Strategic Management Journal*, 27(2): 151-168.

Bertrand, O. and Mol, M. J. (2013), “The antecedents and innovation effects of domestic and offshore R&D outsourcing: The contingent impact of cognitive distance and absorptive capacity”, *Strategic Management Journal*, 34(6): 751-760.

Bertrand, O. (2009),. “Effects of foreign acquisitions on R&D activity: Evidence from firm-level data for France”, *Research Policy*, 38(6): 1021-1031.

Bhalla, A., Sodhi, M. S., and B.-G. Son. (2008), “Is more IT offshoring better?: An exploratory study of western companies offshoring to South East Asia”, *Journal of Operations Management, 26*(2), 322-335

Blomkvist, K., Kappen, P. and I. Zander (2010), “Quo vadis? The entry into new technologies in advanced foreign subsidiaries of the multinational enterprise”, *Journal of International Business Studies*, 41(9): 1525-1549.

Bloom, N., Griffith, R. and J. Van Reenen (2002), “Do R&D tax credits work? Evidence from a panel of countries 1979–1997”, *Journal of Public Economics*, 85(1): 1-31.

Branstetter, L. (2006), “Is foreign direct investment a channel of knowledge spillovers? Evidence from Japan's FDI in the United States”, *Journal of International Economics*, 68(2): 325-344.

Bresman, H., Birkinshaw, J. and R. Nobel (1999), “Knowledge transfer in international acquisitions”, *Journal of International Business Studies*: 439-462.

Brockhoff, K. K. and B. Schmaul (1996), “Organization, autonomy, and success of internationally dispersed R&D facilities”, *Engineering Management, IEEE Transactions on*, 43(1): 33-40.

Cantwell, J. (1995), “The globalisation of technology: what remains of the product cycle model?” *Cambridge Journal of Economics*, 19: 155-155.

Cantwell, J. and R. Mudambi (2005), “MNE competence-creating subsidiary mandates”, *Strategic Management Journal*, 26(12): 1109-1128.

Castellani, D. and F. Pieri (2013), “R&D offshoring and the productivity growth of European regions” *Research Policy*, 42(9): 1581-1594.

Castellani, D., Jimenez, A. and A. Zanfei (2013), “How remote are R&D labs? Distance factors and international innovative activities”, *Journal of International Business Studies*, 44(7): 649-675.

Caves, R. E. (2007), *Multinational Enterprise and Economic Analysis*: Cambridge Univ Pr.

Cavusgil, S. T. and G. Knight (2009), *Born global firms: A new international enterprise*: Business expert press.

Chakrabarti, A., Hauschildt, J. and C. Süverkrüp (1994), „Does it pay to acquire technological firms?”, *R&D Management*, 24(1): 047-056.

Chaudhuri, S. and B. Tabrizi, (1998), “Capturing the real value in high-tech acquisitions”, *Harvard Business Review*, 77(5): 123-130, 185.

Chen, C.-J., Huang, Y.-F. and B.-W. Lin (2012), “How firms innovate through R&D internationalization? An S-curve hypothesis”, *Research Policy*, 41(9): 1544-1554.

Chung, W. and J. Alcácer (2002), “Knowledge seeking and location choice of foreign direct investment in the United States”, *Management Science*, 48(12): 1534-1554.

Chung, W. and S. Yeaple. (2008), "International knowledge sourcing: Evidence from US firms expanding abroad", *Strategic Management Journal*, 29(11): 1207-1224.

Cleves, A., Gould, W., Gutierrez, R. and Y. Marchenko (2010), *Parametric models, An introduction to survival analysis using Stata*, 197-292.

Cloodt, M., Hagedoorn, J. and H. Van Kranenburg (2006), "Mergers and acquisitions: Their effect on the innovative performance of companies in high-tech industries", *Research Policy*, 35(5): 642-654.

Cohen, W. M. and D.A. Levinthal (1990), "Absorptive capacity: a new perspective on learning and innovation", *Administrative Science Quarterly*: 128-152.

Crescenzi, R., Pietrobelli, C. and R. Rabellotti (2013), "Innovation drivers, value chains and the geography of multinational corporations in Europe", *Journal of Economic Geography*: 54-78.

Criscuolo, C., Haskel, J. E. and M.J. Slaughter (2010), "Global engagement and the innovation activities of firms", *International Journal of Industrial Organization*, 28(2): 191-202.

Criscuolo, P. (2009), "Inter-firm reverse technology transfer: the home country effect of R&D internationalization", *Industrial and Corporate Change*, 18(5): 869-899.

D'Agostino, L. M., Laursen, K. and G.D. Santangelo (2013), "The impact of R&D offshoring on the home knowledge production of OECD investing regions", *Journal of Economic Geography*, 13(1): 145-175.

De Backer, K., C. Menon, I. Desnoyers-James and L. Moussiegt (2015), "Reshoring: Myth or Reality?", *STI Policy Paper* No. 27, Paris, OECD Publishing, Paris. http://dx.doi.org/10.1787/5jm56frbm38s-en

Defever, F. (2012), "The spatial organization of multinational firms", *Canadian Journal of Economics/Revue canadienne d'économique*, 45(2): 672-697.

Defever, F. (2006), "Functional fragmentation and the location of multinational firms in the enlarged Europe", *Regional Science and Urban Economics*, 36(5): 658-677.

Delios, A. and W.J. Henisz (2003), "Political hazards, experience, and sequential entry strategies: The international expansion of Japanese firms, 1980–1998", *Strategic Management Journal, 24*(11), 1153-1164.

Di Minin, A. and M. Bianchi (2011), "Safe nests in global nets: Internationalization and appropriability of R&D in wireless telecom", *Journal of International Business Studies*, 42(7): 910-934.

Di Minin, A. and J. Zhang (2010), "An exploratory study on international R&D strategies of Chinese companies in Europe", *Review of Policy Research, 27*(4), 433-455.

Doz, Y. (2006), "Optimizing Metanational Innovation Processes", *Organizational Science*, 40(1): 4.

Doz, Y. L., Santos, J. and P. Williamson (2001), *From global to metanational: How companies win in the knowledge economy*: Harvard Business Press, Boston, Massachusettes.

Dunning, J. H. and S.M. Lundan (2008), *Multinational enterprises and the global economy*: Edward Elgar Publishing, London.

Dunning, J. H. and R. Narula (1995), "The R&D activities of foreign firms in the United States", *International Studies of Management & Organization*, 25(1/2): 39-74.

Ellison, G, E.L. Gleaser and W.R. Kerr (2010), "What causes Industry agglomeration: Evidence from Coagglomeration Patterns", *American Economic Review*, 100, 1195-1213.

Fernández-Ribas, A. and P. Shapira (2009), "Technological diversity, scientific excellence and the location of inventive activities abroad: the case of nanotechnology", *The Journal of Technology Transfer*, 34(3): 286-303.

Florida, R. (1997), "The globalization of R&D: Results of a survey of foreign-affiliated R&D laboratories in the USA", *Research Policy*, 26(1): 85-103.

Fors, G. (1997), "Utilization of R&D results in the home and foreign plants of multinationals", *The Journal of Industrial Economics*, 45(3): 341-358.

Foss, N. J., Lyngsie, J. and S.A. Zahra (2013), "The role of external knowledge sources and organizational design in the process of opportunity exploitation", *Strategic Management Journal*, 34(12): 1453-1471.

Freeman, C. and U. Unit (1987), *Technology, policy, and economic performance: lessons from Japan*: Pinter Publishers.

Freeman, C. (1991), "Networks of innovators: a synthesis of research issues", *Research Policy*, 20(5): 499-514.

Friedman, J., Gerlowski, D. A. and J. Silberman (1992), "What attracts foreign multinational corporations? Evidence from branch plant location in the United States", *Journal of Regional science*, 32(4): 403-418.

Frost, T. S. (2001), "The geographic sources of foreign subsidiaries' innovations", *Strategic Management Journal*, 22(2): 101-123.

Frost, T. S. and C. Zhou (2005), "R&D co-practice and 'reverse'knowledge integration in multinational firms", *Journal of International Business Studies*, 36(6): 676-687.

Furman, J. L. (2003), "Location and organizing strategy: Exploring the influence of location on the organization of pharmaceutical research", *Advances in Strategic Management*, 20: 49-88.

Ghoshal, S., Korine, H. and G. Szulanski (1994), "Interunit communication in multinational corporations" *Management Science*, 40(1): 96-110.

Granstrand, O. and S. Sjölander (1990), "The acquisition of technology and small firms by large firms", *Journal of Economic Behavior & Organization*, 13(3): 367-386.

Grant, R. M. and C. Baden-Fuller (2004), "A knowledge accessing theory of strategic alliances", *Journal of Management Studies*, 41(1): 61-84.

Griffith, R., Harrison, R. and J. Van Reenen (2006), "How Special Is the Special Relationship? Using the Impact of U.S. R&D Spillovers on U.K. Firms as a Test of Technology Sourcing", *American Economic Review*, 96(5): 1859-1875.

Grimpe, C. (2007), "Successful product development after firm acquisitions: The role of research and development", *Journal of Product Innovation Management*, 24(6): 614-628.

Grossman, G. M. and E. Helpman (1991), *Innovation and growth in the global economy*: the MIT Press.

Guellec, D. and B. van Pottelsberghe de la Potterie (2001), "The internationalisation of technology analysed with patent data", *Research Policy*, 30(8): 1253-1266.

Guimón, J. (2011), "Policies to benefit from the globalization of corporate R&D: An exploratory study for EU countries", *Technovation*, 31(2): 77-86.

Guimón, J. (2009), "Government strategies to attract R&D-intensive FDI", *The Journal of Technology Transfer*, 34(4): 364-379.

Gupta, A. K. and V. Govindarajan (2000), "Knowledge flows within multinational corporations", *Strategic Management Journal*, 21(4): 473-496.

Håkanson, L. (1995), "Learning through acquisitions: Management and integration of foreign R&D laboratories", *International Studies of Management & Organization*: 121-157.

Håkanson, L. and R. Nobel (1993), "Foreign research and development in Swedish multinationals", *Research Policy*, 22(5): 373-396.

Head, K., Ries, J. and D. Swenson (1995), "Agglomeration benefits and location choice: Evidence from Japanese manufacturing investments in the United States", *Journal of International Economics, 38*(3-4), 223-247.

Helpman, E. (2006), "Trade, FDI, and the Organization of Firms", *National Bureau of Economic Research Working Paper,* No. 12091.

Henderson, R. and I. Cockburn (1996), "Scale, scope, and spillovers: the determinants of research productivity in drug discovery", *The Rand Journal of Economics*, 27(1): 32-59.

Hewitt, G. (1980), "Research and development performed abroad by US manufacturing multinationals", *Kyklos*, 33(2): 308-327.

Hirschey, R. C. and R.E. Caves (1981), "Research and Transfer of Technology by Multinational Enterprises", *Oxford Bulletin of Economics and Statistics*, 43(2): 115-130.

Iwasa, T. and H. Odagiri (2004), "Overseas R&D, knowledge sourcing, and patenting: an empirical study of Japanese R&D investment in the US", *Research Policy*, 33(5): 807-828.

Jaffe, A. B., Trajtenberg, M., R. Henderson (1993), "Geographic localization of knowledge spillovers as evidenced by patent citations", *The Quarterly Journal of Economics*, 108(3): 577.

Kafouros, M. I., Buckley, P. J. and J. Clegg, J. (2012), "The effects of global knowledge reservoirs on the productivity of multinational enterprises: The role of international depth and breadth", *Research Policy*, 41(5): 848-861.

Kalotay, K., and A. Sulstarova (2010), "Modelling Russian outward FDI", *Journal of International Management, 16*(2), 131-142.

Keupp, A. P. M. M., Palmié, P. C. M. and O. Gassmann (2011), "Achieving subsidiary integration in international innovation by managerial "tools"", *Management International Review*, 51(2): 213-239.

Kogut, B. (1991), "Country capabilities and the permeability of borders", *Strategic Management Journal*, 12(S1): 33-47.

Kogut, B. and U. Zander (1992), "Knowledge of the firm, combinative capabilities, and the replication of technology", *Organization Science*, 3(3): 383-397.

Kuemmerle, W. (1997), "Building effective R&D capabilities abroad", *Harvard Business Review*, 75: 61-72.

Kumar, N. (2001), "Determinants of location of overseas R&D activity of multinational enterprises: the case of US and Japanese corporations", *Research Policy*, 30(1): 159-174.

Lahiri, N. (2010), "Geographic distribution of R&D activity: how does it affect innovation quality?", *Academy of Management Journal*, 53(5): 1194-1209.

Leiponen, A. &and C.E. Helfat (2011), "Location, decentralisation, and knowledge sources for innovation" *Organization Science*, 22(3): 641-658.

Leten, B., Belderbos, R. and B. Van Looy (2007), "Technological diversification, coherence, and performance of firms", *Journal of Product Innovation Management*, 24(6): 567-579.

Lewin, A. Y., Massini, S. and C. Peeters (2009), "Why are companies offshoring innovation? The emerging global race for talent", *Journal of International Business Studies*, 40(6): 901-925.

Leydesdorff, L. and H. Etzkowitz (1996), "Emergence of a Triple Helix of university—industry—government relations", *Science and Public Policy*, 23(5): 279-286.

Lundvall, B. A. (1992*), National innovation system: towards a theory of innovation and interactive learning*. Pinter, London.

Mansfield, E. and A. Romeo (1984), "Reverse' transfers of technology from overseas subsidiaries to American firms", *IEEE Transactions on Engineering Management*, 31: 122-127.

Mariani, M. (2002), "Next to production or to technological clusters? The economics and management of R&D location", *Journal of Management and Governance*, 6(2): 131-152.

Mastercard (2008), *Worldwide Centres of Commerce Index.* Mastercard Publishing, London.

McDougall, P. P., Shane, S. and B.M. Oviatt (1994), "Explaining the formation of international new ventures: The limits of theories from international business research", *Journal of Business Venturing*, 9(6): 469-487.

McFadden, D. (1974), "Conditional logit analysis of qualitative choice behavior" In P. Zarembka (Ed.), *Frontiers in Econometrics.* (pp. 105-142): Academic Press, NY.

McFadden, D. and K. Train (2000), "Mixed MNL models for discrete response", *Journal of Applied Econometrics, 15*(5), 447-470.

Meyer, A. and A. Mizushima (1989), "Global R&D management", *R&D Management*, 19(2): 135-146.

Meyer, K. E., Mudambi, R. and R. Narula (2011), “Multinational enterprises and local contexts: the opportunities and challenges of multiple embeddedness”, *Journal of Management Studies*, 48(2): 235-252.

Meyer-Krahmer, F. and G. Reger (1999), “New perspectives on the innovation strategies of multinational enterprises: lessons for technology policy in Europe”, *Research Policy*, 28(7): 751-776.

Mihalache, O. R., Jansen, J. J., Van Den Bosch, F. A. and H.W. Volberda (2012), “Offshoring and firm innovation: The moderating role of top management team attributes”, *Strategic Management Journal*, 33(13): 1480-1498.

Moncada-Paternò-Castello, P., Vivarelli, M. and P. Voigt (2011), “Drivers and impacts in the globalization of corporate R&D: an introduction based on the European experience”, *Industrial and Corporate Change*, 20(2): 585-603.

Mudambi, R. and P. Navarra. (2004), “Is knowledge power? Knowledge flows, subsidiary power and rent-seeking within MNCs”, *Journal of International Business Studies*, 35(5): 385-406.

Murmann, J. P. (2003), *Knowledge and Competitive Advantage: The co-evolution of firms, technology and national institutions*. Cambridge: Cambridge University Press.

Narula, R. (2002), “Innovation systems and ‘inertia’in R&D location: Norwegian firms and the role of systemic lock-in”, *Research policy*, 31(5): 795-816.

Nelson, R. R. (1993), *National innovation systems: a comparative analysis*: Oxford University Press, USA.

Nieto, M. J. and A. Rodríguez (2011), “Offshoring of R&D: Looking abroad to improve innovation performance”, *Journal of International Business Studies*, 42(3): 345-361.

Nobel, R. and J. Birkinshaw (1998), “Innovation in multinational corporations: control and communication patterns in international R & D operations”, *Strategic Management Journal*, 19(5): 479-496.

Odagiri, H. and H. Yasuda (1996), “The determinants of overseas R&D by Japanese firms: an empirical study at the industry and company levels”, *Research Policy*, 25(7): 1059-1079.

OECD (2013), *Interconnected Economies: Benefitting From Global Value Chains*, OECD Publishing, Paris; http://dx.doi.org/10.1787/9789264174443-zh

OECD (2012), *Redefining Urban: a new way to measure metropolitan areas*, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264174108-en

OECD (2011), *Attractiveness for Innovation: Location Factors for International Investment*, Directorate for Science, Technology and Industry, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264104815-en

OECD (2008), *The Internationalisation of Business R&D: Evidence, Impacts and Implications*, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264044050-en

OECD (2007), *Intellectual Assets and International Investment: A stocktaking of the evidence*, Report to the OECD Investment Committee DAF/INV/WD (2007) 6. Paris: OECD, Paris.

Patel, P. and K. Pavitt (1991), "Large Firms in the Production of the World's Technology: An Important Case of "Non-Globalisation"", *Journal of International Business Studies*: 1-21.

Pearce, R. D. (1999), "Decentralised R&D and strategic competitiveness: globalised approaches to generation and use of technology in multinational enterprises (MNEs)", *Research Policy*, 28(2): 157-178.

Pearce, R. D. (1989), *The internationalisation of research and development by multinational enterprises Macmillan*, London, UK.

Pearce, R. D. and S. Singh (1990), *The internationalisation of research and development by multinational enterprises: a firm-level analysis of determinants*: University of Reading.

Penner-Hahn, J. and J.M. Shaver (2005), "Does international research and development increase patent output? An analysis of Japanese pharmaceutical firms", *Strategic Management Journal*, 26(2): 121-140.

Phene, A. and P. Almeida (2008), "Innovation in multinational subsidiaries: The role of knowledge assimilation and subsidiary capabilities", *Journal of International Business Studies*, 39(5): 901-919.

Pisano, G.P. and Shih, W.C. (2012), "Does America Really Need Manufacturing", *Harvard Business Review*, 90 (3), 94-102.

Porter, M. E. (1991), "Towards a dynamic theory of strategy", *Strategic Management Journal*, 12(S2): 95-117.

Rabbiosi, L. (2011), "Subsidiary roles and reverse knowledge transfer: An investigation of the effects of coordination mechanisms", *Journal of International Management*, 17(2): 97-113.

Revelt, D. and K. Train (1998), "Mixed logit with repeated choices: households' choices of appliance efficiency level", *Review of Economics and Statistics,* 80(4), 647-657.

Rosenkopf, L. and P. Almeida (2003), "Overcoming local search through alliances and mobility. *Management Science",* 49(6): 751-766.

Rugman, A. M. (1981a), *Inside the Multinationals: The Economics of Internal Markets*: C. Helm.

Rugman, A. M. (1981b), "Research and development by multinational and domestic firms in Canada", *Canadian Public Policy/Analyse de Politiques*: 604-616.

Rugman, A., Verbeke, A. and W. Yuan (2011), "Re-conceptualizing Bartlett and Ghoshal's Classification of National Subsidiary Roles in the Multinational Enterprise", *Journal of Management studies*, 48(2): 253-277.

Saxenian, A. (1994), *Regional Advantage: competition and cooperation in Silicon Valley and Route 128*: Cambridge, MA: Harvard University Press.

Schmiele, A. (2012), "Drivers for international innovation activities in developed and emerging countries", *The Journal of Technology Transfer*, 37(1): 98-123.

Shaver, J. and F. Flyer (2000), "Agglomeration economies, firm heterogeneity, and foreign direct investment in the United States", *Strategic Management Journal*, 21(12): 1175-1193.

Shimizutani, S. and Y. Todo, Y. (2008), "What determines overseas R&D activities? The case of Japanese multinational firms", *Research Policy*, 37(3): 530-544.

Siedschlag, I., Smith, D., Turcu, C. and X. Zhang (2013), "What determines the location choice of R&D activities by multinational firms?" *Research Policy*, 42(8): 1420-1430.

Singh, J. (2008), "Distributed R&D, cross-regional knowledge integration and quality of innovative output", *Research Policy*, 37(1): 77-96.

Song, J. and J. Shin (2008), "The paradox of technological capabilities: What determines knowledge sourcing from overseas R&D operations", *Journal of International Business Studies*, 39: 291-303.

Song, J., Asakawa, K. and Y. Chu (2011), "What determines knowledge sourcing from host locations of overseas R&D operations?: A study of global R&D activities of Japanese multinationals", *Research Policy*, 40(3): 380-390.

Subramaniam, M. and N. Venkatraman (2001), "Determinants of transnational new product development capability: Testing the influence of transferring and deploying tacit overseas knowledge", *Strategic Management Journal*, 22(4): 359-378.

Thomson, R. (2009), "Tax policy and the globalisation of R&D", *Working papers in Trade and Development. The Australian National University working paper*, 3: 1-74.

Train, K. (2003), *Discrete choice methods with simulation*: Cambridge: Cambridge Univ Press.

UNCTAD. (2005), *World Investment Report*: *Transnational Corporations and Internationalization of R and D*. New York: United Nations.

Vernon, R. (1979), "The product cycle hypothesis in a new international environment", *Oxford Bulletin of Economics and Statistics*, 41(4): 255-267.

Von Zedtwitz, M. and O. Gassmann (2002), "Market versus technology drive in R&D internationalization: four different patterns of managing research and development", *Research Policy*, 31(4): 569-588.

Warda, J. (2006), "Tax treatment of business investments in intellectual assets: an international comparison", *OECD Science, Technology and Industry Working Papers*, No. 2006/04, http://dx.doi.org/10.1787/672304513676.

Zanfei, A. (2000), "Transnational firms and the changing organisation of innovative activities". *Cambridge Journal of Economics*, 24(5): 515-542.

ANNEX 1. PULL LOACTION FACTORS ATTRACTING RDDT INVESTMENTS AT THE CITY LEVEL

Model

Conditional logit

Within the location choice literature (e.g. Alcácer and Chung, 2007; Head *et al.*, 1995), the conditional logit model (McFadden, 1974) has been widely used to analyse the location determinants of foreign direct investments. The conditional logit model is built on the Random Utility (Profit) Maximization Framework, developed by McFadden (1974). In this framework, a chooser labelled i (i=1,…,N), chooses one option from among a choice set j(j=1,…,J) with the aim to maximize utility. In the context of firms' foreign R&D location choices, the expected utility of a location for an investing firm (U_{ij}) is modeled in terms of the observable characteristics of the location (X_{ij}) and an unknown error term(ε_{ij}).

$$U_{ij} = \beta' X_{ij} + \varepsilon_{ij} \qquad (1)$$

In our empirical model, global cities form the location set and the observable characteristics of these cities represent the independent variables. McFadden (1974) demonstrated that if the errors terms are independently and identically distributed with type 1 extreme-value distribution, the probability of choosing alternative k (a global city) is given by the following formula:

$$P(y_i = k) = \frac{exp(x_{ik}\beta)}{\sum_{j=1}^{J} exp(x_{ij}\beta)}, k \in J \qquad (2)$$

The conditional logit model has one important drawback, namely that it only provides consistent estimates under the assumption of independence of irrelevant alternatives (IIA). This property states that for any two alternatives the ratio of probabilities is independent of the characteristics of any other alternative in the choice set. This implies that the change in an attribute of any other alternative may not change the relative probabilities of the two alternatives. Accordingly, the relative probability of any two alternatives is independent of the inclusion or removal of other alternatives. This characteristic also implies the absence of correlations between error terms across alternatives. This assumption is however frequently violated in location choice analyses. Recent studies (e.g. Basile *et al.*, 2008; Chung and Alcácer, 2002) have therefore used the mixed logit model, which does not rely on the IIA assumption (McFadden and Train, 2000). Likewise, we will also use mixed logit models.

Mixed logit

Similarly to the conditional logit models, mixed logits also start from a random utility maximization setting to examine location choices of R&D investments. Having a choice set of alternative host regions r = 1,… R to locate an overseas R&D project at time t, a multinational firm f seeks to maximize its expected utility $(U_{fr,t})$ as a function of observable regional attributes and unobservable regional factors ε_{fr}.

The expected utility of a multinational firm *f* choosing region *r* among other host regions at time *t* can be expressed by the function:

$$U_{fr,t} = \alpha X_{fr,t-1} + \varepsilon_{fr} \tag{3}$$

In this function, $X_{fr,\ t-1}$ represents a vector of region-specific characteristics that can vary across industries or firms, while ε_{fr} defines a region-specific independent random disturbance term. While the standard conditional logit model restricts the coefficients α to be equal across firms, the mixed logit allows the coefficients to follow a distribution function. Accordingly, coefficients are decomposed into a fixed part and a random part that accounts for unobservable effects. The error term incorporates the random components of the coefficients and takes the following form:

$$\varepsilon_{fr} = \lambda_f Z_{fr,t-1} + \mu_{fr} \tag{4}$$

where $Z_{fr,t-1}$ is a vector of observable variables while λ_f is a vector of randomly distributed parameters with zero mean following a normal distribution with variance Ω. The parameter μ_{fr} is an independent and identically distributed error term. If the parameter λ_f would be observed, the probability that a firm *f* would locate its foreign R&D investment in city *r* could be expressed as a standard logit model. However, since the coefficients in the mixed logit model are not known but are assumed to follow a certain density function $g(\lambda_f)$, the locational choice probability has to be calculated over all possible values of λ_f. The mixed logit probability is therefore obtained by taking the integral of the multiplication of the conditional probability with the density functions describing the random nature of the coefficients. This is described by the following equation:

$$P_{fr} = \int \frac{\exp(\alpha X_{fr,t-1} + \lambda_f Z_{fr,t-1})}{\sum_{j=1}^{J} \exp(\alpha X_{fj,t-1} + \lambda_f Z_{fj,t-1})} g(\lambda_f) d(\lambda_f) \tag{5}$$

Given the fact that the mixed logit estimates are more general, these estimates should be considered more reliable. The estimated random parts of the coefficients indicate that there is substantial unobserved heterogeneity at the firm level in the drivers of location choices. The estimates of the coefficients of the mixed logit model are the averages across investors, allowing for such heterogeneity.

The analysis of these location decisions has been conducted at the city level. The analysis focuses on RDDT projects identified in the fDi Markets dataset (2003-2012) that are located in the set of 57 cities (in 32 countries) for which detailed information on the investment environment for RDDT (along which patent information) is collected. The most general model includes 57 cities and all RDDT projects in these cities, 2003-2011: 1,883 projects by 931 parent firms. Including the B-index reduces the number of investments in the analysis to 1 099 projects by 624 parent companies as this information is not available for quite a few countries (mostly non-OECD members), or only available in more recent years. The inclusion of the B-index therefore reduces the number of cities and city years that can be included. Dubai, Bangkok, Hong Kong, China have no information during the period, and a number of other cities only have information from 2008 onwards (e.g. Shanghai, Beijing, Rio de Janeiro, Mumbai).

Explanatory variables

Patent related variables

To define the boundaries of each global city, the OECD methodology of metropolitan regions has been used to enable a uniform comparison of cities across countries. National governments often define their metropolitan areas on the basis of legal boundaries. This approach, however, often does not coincide with the actual agglomeration of the city and does not take changing population patterns into account. In contrast, the OECD (OECD, 2012) developed a methodology based on a harmonized definition that identifies urban areas as functional economic units, using population density and travel-to-work flows as key information. In this way, urban areas can be characterized by densely populated "urban cores" and "hinterlands" whose labour market is highly integrated with the cores.[1]

To allocate patents to global cities (i.e. metropolitan areas), the OECD REGPAT Database has been used providing region indicators for each patent, utilizing the addresses of the applicants and inventors. The database currently covers more than 5 500 regions across OECD countries, EU-27 countries, Brazil, China, India, Russia and South Africa. The REGPAT database derives its data from the European Patent Office's Worldwide Statistical Patent Database (PATSTAT, October 2012). We use patents filed under the Patent Co-operation Treaty (PCT).[2] The PCT provides a unified procedure for filing patent applications to protect inventions in each of the contracting states of the PCT. These patents are generally applied for inventions for which firms seek protection in various regions (e.g. The US, the EU, and Japan) and are the least likely to exhibit a regional or city bias.

The regional breakdowns provided in REGPAT correspond to NUTS-3 regions (Nomenclature of territorial units for statistics) for European countries and TL3 regions (Territorial level) for other countries. Patents are assigned to global cities based on the regionalized addresses of the inventors that are listed on the patents. Using inventor addresses is more accurate than using assignee (patent applicant) addresses because firms tend to use the headquarters' address as assignee address, instead of the subsidiary's address or the address where the invention originated (Deyle and Grupp, 2005). Inventions were matched to global cities based on available concordance tables linking NUTS-3/TL3 regions with metropolitan areas. However, such concordance does not exist for all cities and the geographical breakdown for some OECD countries is less detailed (some countries only have TL2 regions). For these cases, use has been made of available maps of the geographical demarcation of the metropolitan areas and the OECD TL2/TL3 regions to link both regions and extend the existing concordance tables. For the Australian cities in the sample (Melbourne and Sydney), the OECD (2012) identifies the TL3 regions as appropriate proxies for metropolitan areas. Accordingly, for these cities the metropolitan areas and the TL3 regions coincide.

To improve the coverage of worldwide RDDT investments, 7 cities for which the OECD does not construct metropolitan areas have been added: Mumbai, Bangalore (India), Chinese Taipei, Rio de Janeiro (Brazil), Moscow (Russia), Bangkok (Thailand), and Dubai (UAE). Of these 7 cities, only the first 5 are included in the OECD REGPAT database. To allocate patents to these cities, the patents of the regions in which these global cities are located have been identified. However, since the regions covered in the OECD REGPAT database for the countries of these global cities are TL2 regions, these regions are often too big to represent any global city (except for Russia which has a TL2 region that coincides with the city of Moscow). Accordingly, based on the exact address of each inventor located in the region string matching has been used and postal codes to allocate patents to each global city. But in order to take the true agglomeration size of the city into account, patents of inventors located in the close vicinity are also allocated to that global city. Cities and towns are allocated to the global city if they are located within a 100 km radius of the global city. This approach is in accordance with empirical findings that knowledge spillovers and commuting patterns are very frequent in such a radius (Belenzon and Shankerman, 2012; OECD, 2012). For the cities not covered by the OECD REGPAT database (Bangkok and Dubai), EPO's Worldwide PATSTAT database (version October 2012) has been used. After extraction from the database all PCT patents by inventors living in Thailand and the United Arab Emirates, patents have been allocated to these final two global cities again based on the address information of these inventors.

In order to allocate patents to industries, the patent technology class to industry concordance table developed by Schmoch et al. (2003) has been used. This concordance table links the technology codes (IPC) of the patents to their corresponding NACE code at the two-digit level. These NACE codes are matched with the industry codes for investing firms available in the fDi Markets database. Twelve 2-digit NACE manufacturing industries (food, tobacco and beverages; textiles; paper, print and wood; chemicals; pharmaceuticals; rubber; minerals; metals; machinery; electronics; transport; others) are distinguished. If a patent lists multiple inventors and IPC classes, ‘fractional counts’ to assign the patent to a global city and industry are used: a patent is assigned to an IPC class proportional to the share of that IPC class in all IPC classes of the patent (e.g. if a patent lists two IPC classes, the patent contributes 0,5 to each IPC class). Full patent counts would artificially increase the patent counts for cities with patents involving multiple inventors.

Three variables derive from the patent data. The variable *technological strength* is the fractional count of the number of patents invented in a city’s metropolitan area and classified in the industry of the investing firm, divided by the total sum of patents over all global cities classified in that industry. Scaling by the world’s total number of patents takes into account the variation in patent counts across industries.

The variable *international R&D collaboration* of the global city is constructed by collecting information about the inventor’s collaboration on patents. When a patent with an inventor in a global city involves at least one co-inventor residing outside the global city’s country, we count this as an international collaborative linkage. The measure of international R&D collaboration intensity is then constructed as the share of patents with international knowledge linkage(s) over the total number of patents in the city. This measure defines the connectedness of the focal global city to regions outside the global city’s country and how globally connected the city is. The collaboration measure is also calculated at the industry level.

As indicator for *university strength* is based on all university patents invented in the global city. A patent is considered to be a university patent, if at least one of the assignees is a university; sector allocation algorithms to identify patents with universities as assignees are used. University strength is measured as the share of university patents in the total patents of the global city. The variable is an indicator of the relative strength of universities research present in the global city and the entrepreneurial orientation of these universities in terms of their aims to commercialize the output of research efforts. Results are also reported with an alternative measure of university strength: the number of world *top 500 universities* in the city. Data on world top 500 universities comes from the Times Higher Education yearly rankings.

Other variables

The variable *city GDP* is a measure of the size of the economy of the city. In addition to GDP levels, R&D investments are likely to be attracted to economic regions exhibiting a strong market growth as this signals a positive evolution of the host market and captures future market potential. Market growth is proxied by calculating the *GDP growth rate* as the yearly growth in GDP. The analysis also takes into account the *population density* of the city defined as population divided by surface area of the city. Greater density may on the one hand represent stronger agglomeration benefits of the city; and on the other hand, high density may imply congestion costs. Linear and squared terms of the natural log of population density are included in the models. Data on city population and GDP are drawn from the OECD’s metropolitan data and Citymayor data, and data on surface areas of cities are retrieved from various sources including city websites.

High wage costs have been found to discourage HQ investments (Davis and Henderson, 2008; Strauss-Kahn and Vives, 2009). Data on *wage levels of skilled employees at the city level* are obtained from the UBS’ Price and Earnings reports.

Data on the c*orporate tax rates* come from KPMG and are at the country level, as there is no or little difference in the corporate tax rate between the country and the city level. Although several studies have found a negative effect of corporate tax rate on R&D location decisions (e.g. Hines, 1995; Mudambi and

Mudambi; 2005), some studies have also documented that this effect is negligible (e.g. Cantwell and Mudambi; 2000).

The variable *IPR protection* is taken from the Global Competitiveness Report published by the World Economic Forum. This index is constructed based on the opinions of multinational firms and experts on the strength of patents, trademarks and copyright protection; it takes values between 0-10, with high scores for intellectual property right systems that are highly aligned with international standards**.**

Socio-political stability of the global city is included as this factor may have a positive effect on attracting foreign direct investment. Data on socio-political stability were provided by the Economist Intelligence Unit (EIU).

Airport infrastructure has been found to attract foreign investments in particular in HQ operations (Bel and Fageda, 2008), since MNEs value the connectivity of cities. As an imperfect indicator of the quality of airport infrastructure we include the yearly number of passengers recorded at the global cities' airports (airport traffic), drawing primarily individual airports' websites. Airport passenger flows are normalised by expressing passenger numbers as an index relative to the number of airport passengers recorded in the particular year for London –with the index for London set at 100.

A dummy variable indicating *language similarity* between the global city and the source city of the investing firm is also included. It takes the value of one when the two cities share at least one official language, and zero, otherwise. Since shared language facilitates cross-border communication and collaboration between the home country and host country (Guellec and Van Pottelsberghe, 2001), firms may have a preference for cities that utilize a shared language. The data is obtained from the CEPII database which provides information about languages spoken in countries around the world.

Language issues may be less salient if the *English language proficiency* in the host country is strong, and English language proficiency can reduce communication costs and facilitates multinational firms' business activities. Following Slangen (2011) and Cuypers, Ertug and Hennart (2015), the average TOEFL (Test of English as a Foreign Language) scores published by Educational Testing Services (ETS) divided by the maximum score that an examinee can obtain as the measure of English language proficiency has been used. In addition, an interaction effect of *English language proficiency* and *language similarity* is included: if English language proficiency is high, a shared language is less important, or conversely, if there is a shared language (e.g. French firms investing in Brussels), English language proficiency is less important.

The *geographic distance* between the city and the source city of the firm is included, as a larger distance can have a negative impact on R&D investments location decision due to increasing informational uncertainty and coordination costs (e.g. Castellani et al., 2011). The geographic distance between the city and source city is calculated using the latitude and longitude of each city (source: genonames.org). Geographic distance is measured as the great circle distance between the source and the destination city, defined as the shortest distance between two points on the surface of a sphere, measured along a path on the surface of the sphere.

The extent of *R&D tax incentives* is measured by the B-index, which is calculated as the present value of before-tax income that a firm needs to generate in order to cover the cost of the initial R&D investment and to pay the applicable income taxes (Thomson, 2009). In other words, the B-index represents the net cost for the firm to invest in R&D. It takes into account R&D tax incentives such as tax credits, cost allowances from taxable income, depreciation allowances and the corporate income tax rate (Warda, 2001). When the B-index equals one, the R&D expenditures are fully deductible as costs, although offering no implicit subsidy to the investing firm. A B-index lower than one indicates that the R&D costs are more than fully deductible, which implies that investing firms benefit from R&D tax incentives. In the opposite case, when the B-index has a value higher than one, R&D investments lead to a tax burden. The main advantage of the B-index is that it facilitates international comparison of R&D tax treatments. It is measured at the country level, as in most countries taxation is a federal responsibility and does not vary by city or region.[3].The main source for the B-index (for large firms; given that most RDDT investment is undertaken by MNEs) is the OECD STI Scoreboard (various years). Additional information was obtained from the Database for Institutional Comparison in Europe (DICE) for European countries, Warda (2009) for Brazil, China, India, Russia and Singapore, and The Information Technology & Innovation Foundation (ITIF) for Singapore and Russia.

Results

Table A1.1 presents the results for the full sample of cities; table A1.2 presents the results for the reduced .sample of cities for which information on R&D tax incentives is available (the first two columns report estimates without adding the B-index to examine if estimates change due to sample attrition). The positive effects of university strength, political stability, English language proficiency, language similarity and their interaction are no longer significant in these models. In contrast, IPR protection now has a significantly positive effect. This may be due to smaller set of projects and cities in the reduced sample, which has a closer focus on OECD countries. The smaller variation in the language differences, English proficiency and political stability may render it more difficult to identify effects, while among cities with roughly more similar core characteristics (e.g. in terms of technological strength), the role of taxation and IPR protection may become more salient.

Table A1.1. Determinants of the Location choice of RDDT (all projects), RRD (research, R&D) and DDT (development, design and testing) investments, full sample

	RDDT (all projects)		**RRD**		**DDT**	
Variables	clogit	mixlogit	clogit	mixlogit	clogit	mixlogit
Technological strength	0.287***	0.269***	0.278*	0.289*	0.301***	0.297**
	(0.0898)	(0.0960)	(0.151)	(0.157)	(0.108)	(0.124)
International R&D collaboration	0.168***	0.476***	0.108	0.333***	0.193***	0.541***
	(0.0516)	(0.0625)	(0.0808)	(0.0945)	(0.0605)	(0.0829)
University strength	0.471***	0.590***	0.776***	0.841***	0.311***	0.447***
	(0.0821)	(0.0824)	(0.131)	(0.131)	(0.103)	(0.109)
GDP	0.0428	0.208**	-0.132	-0.0449	0.129	0.334***
	(0.0716)	(0.0854)	(0.114)	(0.130)	(0.0885)	(0.110)
GDP growth	0.0964***	0.109***	0.0904***	0.103***	0.101***	0.116***
	(0.00737)	(0.00916)	(0.0123)	(0.0137)	(0.00931)	(0.0110)
Population density	0.841***	2.559***	1.050***	2.427*	0.751***	2.990***
	(0.160)	(0.921)	(0.266)	(1.332)	(0.191)	(0.946)
Population density squared	-0.108***	-0.365***	-0.141***	-0.347*	-0.0932***	-0.422***
	(0.0230)	(0.128)	(0.0388)	(0.188)	(0.0273)	(0.131)
Political-social stability	1.697***	2.146***	2.715***	2.962***	1.305***	1.924***
	(0.226)	(0.260)	(0.398)	(0.398)	(0.272)	(0.308)
Language similarity	8.698***	12.28***	16.64***	21.04***	5.278*	7.692**
	(2.613)	(2.966)	(4.382)	(4.919)	(3.202)	(3.749)
Geographic distance	0.0712*	0.0869	0.00765	-0.0137	0.104**	0.247***
	(0.0374)	(0.0691)	(0.0612)	(0.0660)	(0.0473)	(0.0828)
Wage level	-0.898***	-0.975***	-0.987***	-1.049***	-0.871***	-0.963***
	(0.0506)	(0.0633)	(0.0995)	(0.115)	(0.0569)	(0.0722)
Corporate tax rate	0.0230	0.298*	0.126	0.291**	-0.00865	0.359**
	(0.0732)	(0.172)	(0.125)	(0.130)	(0.0867)	(0.172)
IPR protection	0.0284	0.0679	-0.246	-0.144	0.187	0.162
	(0.163)	(0.191)	(0.251)	(0.282)	(0.210)	(0.231)
Airport traffic index	0.656***	-0.0806	0.321	-0.270	0.812***	0.0235
	(0.195)	(0.258)	(0.325)	(0.416)	(0.250)	(0.311)
English language proficiency	0.0526	0.663*	0.240	0.594	-0.00948	0.757*
	(0.285)	(0.343)	(0.523)	(0.563)	(0.345)	(0.409)
Language similarity*English proficiency	-1.808***	-2.629***	-3.593***	-4.599***	-1.040	-1.608*
	(0.591)	(0.669)	(0.992)	(1.116)	(0.723)	(0.843)
Random parts coefficients						
International R&D collaboration		0.919***		0.751***		0.991***
GDP		0.725***		0.505***		0.878***
Population density		0.711**				0.861***
Geographic distance						0.557***
Corporate tax rate		0.467**				0.664***
English language proficiency		2.179*		3.600***		0,543***
Observations	95,902	95,902	30,210	30,210	65,692	65,692

Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A1.2. Determinants of the Location choice of RDDT (all projects), RRD (research, R&D) and DDT (development, design and testing) investments, reduced sample (B-index available)

	Comparison model		B-index		RRD		DDT	
Variables	clogit	mixed logit	clogit	mixedlogit	clogit	mixed logit	clogit	mixed logit
Technological strength	0.463***	0.594***	0.475***	0.631***	0.482***	0.692***	0.510***	0.658***
	(0.104)	(0.110)	(0.102)	(0.108)	(0.169)	(0.189)	(0.121)	(0.136)
International R&D collaboration	0.129**	0.427***	0.110*	0.415***	-0.0325	0.185	0.147**	0.488***
	(0.0635)	(0.0791)	(0.0635)	(0.0801)	(0.109)	(0.139)	(0.0743)	(0.103)
University strength	-0.0317	0.0606	-0.0372	0.0680	0.295*	0.354**	-0.201	-0.0507
	(0.0967)	(0.104)	(0.0985)	(0.112)	(0.156)	(0.179)	(0.126)	(0.144)
GDP	0.419***	0.404***	0.384***	0.352***	0.0264	0.0471	0.504***	0.522***
	(0.0904)	(0.108)	(0.0917)	(0.108)	(0.148)	(0.180)	(0.114)	(0.138)
GDP growth	0.0855***	0.0868***	0.0925***	0.0985***	0.0577***	0.0702***	0.105***	0.109***
	(0.0122)	(0.0135)	(0.0122)	(0.0139)	(0.0219)	(0.0262)	(0.0156)	(0.0174)
Population density	0.596***	1.791*	0.571***	2.189**	0.924***	2.899**	0.460**	1.494*
	(0.167)	(0.973)	(0.168)	(1.061)	(0.269)	(1.466)	(0.208)	(0.845)
Population density squared	-0.0919***	-0.272**	-0.0880***	-0.328**	-0.126***	-0.425**	-0.0743**	-0.238**
	(0.0243)	(0.133)	(0.0245)	(0.145)	(0.0392)	(0.205)	(0.0302)	(0.115)
Political-social stability	-0.0672	-0.459	-0.0763	-0.555	1.477**	1.047	-0.334	-0.801*
	(0.366)	(0.409)	(0.372)	(0.404)	(0.734)	(0.828)	(0.408)	(0.469)
Language similarity	4.350	4.970	3.424	5.541	17.83***	24.02***	-3.139	-3.569
	(3.921)	(4.548)	(3.953)	(4.599)	(6.183)	(9.156)	(4.764)	(5.355)
Geographic distance	0.0183	0.0355	0.0262	0.0309	0.0845	0.104	0.0109	0.0457
	(0.0428)	(0.0541)	(0.0432)	(0.0542)	(0.0775)	(0.0952)	(0.0531)	(0.100)
Wage level	-0.624***	-0.624***	-0.553***	-0.555***	-0.638***	-0.802***	-0.609***	-0.595***
	(0.0849)	(0.0953)	(0.0882)	(0.106)	(0.169)	(0.200)	(0.0947)	(0.121)
Corporate tax rate	-0.627***	-0.541**	-0.799***	-0.836***	-1.614***	-1.615***	-0.331	-0.347
	(0.181)	(0.222)	(0.188)	(0.192)	(0.249)	(0.283)	(0.219)	(0.227)
IPR protection	1.362***	1.524***	1.413***	1.692***	1.490***	2.151***	1.463***	1.591***
	(0.240)	(0.283)	(0.252)	(0.306)	(0.480)	(0.604)	(0.291)	(0.351)
Airport traffic index	0.219	-0.0751	0.264	-0.105	0.166	-0.396	0.421	0.000176
	(0.226)	(0.281)	(0.232)	(0.285)	(0.419)	(0.565)	(0.289)	(0.355)
English language proficiency	-0.209	-0.230	-0.310	-0.249	-0.292	0.607	-0.202	-0.0420
	(0.420)	(0.452)	(0.433)	(0.509)	(0.815)	(1.082)	(0.482)	(0.560)
Language similarity*English proficiency	-0.859	-1.015	-0.654	-1.148	-3.843***	-5.302***	0.796	0.863
	(0.880)	(1.024)	(0.887)	(1.034)	(1.390)	(2.058)	(1.068)	(1.201)
B-index			-0.987***	-0.857*	-2.516***	-1.896***	-0.334	-0.259
			(0.267)	(0.444)	(0.462)	(0.727)	(0.312)	(0.594)
Random parts coefficients								
International R&D collaboration		0.894***		0.931***		0.737***		1.049***
GDP								0.529***
Population density								0.524*
Population density squared						0.0752**		
Language similarity						1.514*		
English language proficiency				4.323***		6.826***		
B-index				2.579***		4.888***		
Observations	48,308	48,308	48,308	48,308	14,819	14,819	33,489	33,489

Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

ANNEX 2. PUSH LOCATION FACTORS DRIVING OUTWARD RDDT INVESTMENTS AT THE CITY LEVEL

Model

The cross-border RDDT decision in general is not a frequent event at the firm level. The most appropriate method to relate RDDT investments to firm and home region characteristics is either a binary choice model (probit or logit models) or a hazard model. Binary choice models evaluate the probability that firm i in region j invests in RDDT abroad in each individual year t, treating the outcome (investment or not) each year as a separate event. Hazard models take the time dimension of the RDDT investment decision more explicitly into account and estimate the "time lapsed" until a firm invests in RDDT. In case of multiple investments, a "repeated hazard" model is estimated. Hazard models (such as the Cox model) have the advantage that they allow for "right censoring" - firms that do not invest within the period.

Previous studies on foreign direct investments (Delios & Henisz, 2003; Belderbos, Tong and Wu, 2014) employ hazard, or "duration", models, such as the semiparametric Cox model which has the advantage that it does not require specifying the baseline hazard function (Cleves, Gould, Gutierrez, & Marchenko, 2010). However, the Cox proportional hazard model assumes that time is continuous and that the exact timing of events is registered. This is not the case for the investment data in this dataset as only the year of the event is available. Recent developments in statistics and statistical software (STATA) suggest that in this case a simplified form of the Cox model can be used: the complementary log model.

The log function specifies the hazard that a firm i performs a foreign RDDT investment during year t as a function of a baseline hazard $\lambda(t)$ and a firm-specific element $x_{it}b$, where: x_{it} are firm-specific variables or city of origin specific variables:

$$\lambda(t|x_{it})=1- \exp(- \exp (x_{it}b + \lambda_t)) \qquad (1)$$

This equation can be transformed into the loglog function as:

$$\log(-\log(1-\lambda(t|x_{it})))=\alpha_t+x_{it}b \qquad (2)$$

where $\alpha_t=\log(-\log(1-\lambda_j))$ is the complementary log-log transformation of the baseline hazard. Instead of coefficients, which are difficult to interpret directly, *hazard ratios* are reported. These indicate the 1+ percentage increase in the probability of RDDT investments as a result of a 1 unit increase in the regressors.

The analysis has been conducted at the firm-year level. The analysis first of all focuses on firms engaging in RDDT projects identified in the fDi Markets dataset (2003-2011) that have their headquarters in a set of 57 global cities (in 32 countries) for which detailed information on the investment environment for RDDT is collected. To explore generality of the findings, analysis has also been conducted for an expanded group of multinational firms. In particular, the expanded analysis includes firms that are engaged in other cross-border activities according to the fDi Markets database, where a distinction is made between those firms holding patents and firms not holding patents. The additional firms serve as an ad hoc control group in the analysis, while the patent holding group has greater similarity in characteristics to the RDDT investing firms.

Variables

City of Origin Variables

City of origin variables included follow the set of variables that have been included in the location models identifying "pull" factors (see Annex 1).

The variable *technological strength* is the fractional count of the number of patents invented in a city's metropolitan area and classified in the industry of the investing firm, divided by the total sum of patents over all global cities classified in that industry. Scaling by the world's total number of patents takes into account the variation in patent counts across industries.

The variable *international R&D collaboration* of the global city is constructed by collecting information about the inventor's collaboration on patents. When a patent with an inventor in a global city involves at least one co-inventor residing outside the global city's country, this is counted as an international collaborative linkage. The measure of international R&D collaboration intensity is then constructed as the share of patents with international knowledge linkage(s) over the total number of patents in the city. This measure defines the connectedness of the focal global city to regions outside the global city's country and how globally connected the city is. The collaboration measure is also calculated at the industry level.

University strength is based on all university patents invented in the global city with patents being considered to be university patents, if at least one of the assignees is a university. Sector allocation algorithms have been used to identify patents with universities as assignees. University strength is calculated as the share of university patents in the total patents of the global city. The variable is an indicator of the relative strength of university research present in the global city and the entrepreneurial orientation of these universities in terms of their aims to commercialize the output of research efforts.

The variable *city GDP* is a measure of the size of the economy of the city; the variable *GDP growth rate* measures the yearly growth rate of city GDP. The analysis also takes into account the *population density* of the city defined as population divided by surface area of the city. Again, linear and squared terms of the natural log of population density are included.

Data on *wage levels of skilled employees at the city level* are obtained from the UBS' Price and Earnings reports. Data on the c*orporate tax rates* come from KPMG and are at the country level, as there is no or little difference in the corporate tax rate between the country and the city level. The variable *IPR protection* is taken from the Global Competitiveness Report published by the World Economic Forum. This index is constructed based on the opinions of multinational firms and experts on the strength of patents, trademarks and copyright protection; it takes values between 0-10, with high scores for intellectual property right systems that are highly aligned with international standards**.** As an imperfect indicator of the quality of airport infrastructure, the yearly number of passengers recorded at the global cities' airports (*airport traffic*).

The extent of *R&D tax incentives* is measured by the B-index, which is calculated as the present value of before-tax income that a firm needs to generate in order to cover the cost of the initial R&D investment and to pay the applicable income taxes (Thomson, 2009). In other words, the B-index represents the net cost for the firm to invest in R&D. It takes into account R&D tax incentives such as tax credits, cost allowances from taxable income, depreciation allowances and the corporate income tax rate (Warda, 2001). When the B-index equals one, the R&D expenditures are fully deductible as costs, although offering no implicit subsidy to the investing firm. A B-index lower than one indicates that the R&D costs are more than fully deductible, which implies that investing firms benefit from R&D tax incentives. In the opposite case, when the B-index has a value higher than one, R&D investments lead to a tax burden. The main advantage of the B-index is that it facilitates international comparison of R&D tax treatments. It is measured at the country level, as in most countries taxation is a federal responsibility and does not vary by city or region. The main source for the B-index (for large firms; given that most RDDT investment is undertaken by MNEs) is the OECD STI Scoreboard (various years). Additional information was obtained from the Database for Institutional Comparison in Europe (DICE) for European countries, Warda (2009) for Brazil, China, India, Russia and Singapore, and The Information Technology & Innovation Foundation (ITIF) for Singapore and Russia.

Finally, all models include a set of *time dummies*.

A number of variables featuring in the location analysis (see Annex 1) are not included in the context of the analysis here. First, variables that are measuring home-host country characteristics (language distance, geographic distance) are not suitable for analysis examining RDDT investments propensities in general. Second, English language proficiency and political stability had no significant effect throughout the series analysis and different specification. Given their relative high correlation with other variables they omitted from the models of which the results are reported.

In order to explore potential correlations between inward RDDT and outward RDDT of cities, the number of *incoming RDDT investments* in the city and sector is included.

Firm level variables

Firm level variables include a set of variables that are well available across firms present in the ORBIS database: *age and age squared* (years since establishment of the firm), *firm size* dummies, and the (natural log of the) *number of patents* the firm holds. For the size classes, use has been made of the indicators provided in ORBIS: small companies (the reference group) have fewer than 15 employees or sales less than 1 million Euros, medium-sized companies have between 15 and 150 employees, large companies have between 150 and 1 000 employees, and very large companies have more than 1 000 employees.

The *number of patents* is the total number of patent records assigned to the parent firm in the ORBIS database. In addition to these basic variables, a number of models also include financial variables from ORBIS like (the natural log of) *turnover* and *return on assets*. In general these are less well available for all firms, explaining the smaller number of observations.

Results

Table A2.1 presents the results for the city of origin factors only, while table A2.2 also includes firm-level variables. Models 3 and 6 in both tables only include the firms that have implemented RDDT projects abroad during the period 2003-2011. Models 2 and 5 add a control group of firms that did not have RDDT projects abroad but did hold patents, while models 1 and 4 add a broader control group of MNEs (both holding and not holding patents). Because of the availability of the B-index, the inclusion of this variable resulted in a reduced sample of cities taken into account (see also Annex 1).

Table A2.1. The propensity to engage in foreign RDDT investments: city of origin effects

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
technological strength	1.280***	1.059	1.087	1.267***	1.047	1.093
	(0.108)	(0.077)	(0.073)	(0.113)	(0.081)	(0.078)
International R&D. collab.	1.111*	0.974	0.958	1.096	0.952	0.940
	(0.069)	(0.048)	(0.044)	(0.079)	(0.052)	(0.049)
University strength	0.740***	0.851***	0.890**	0.698***	0.790***	0.839**
	(0.054)	(0.051)	(0.050)	(0.063)	(0.062)	(0.062)
gdp	0.803**	0.790***	0.832**	0.809**	0.787***	0.832**
	(0.079)	(0.068)	(0.070)	(0.080)	(0.068)	(0.071)
gdp growth	1.013	1.010	1.011	1.023	1.024	1.025
	(0.015)	(0.015)	(0.014)	(0.018)	(0.017)	(0.017)
population density	0.996	1.375**	1.247	1.014	1.368**	1.214
	(0.174)	(0.209)	(0.173)	(0.182)	(0.212)	(0.172)
population density sq.	1.021	0.969	0.975	1.019	0.970	0.979
	(0.026)	(0.021)	(0.019)	(0.026)	(0.021)	(0.020)
wage	1.092	1.182**	1.241***	1.100	1.258**	1.302***
	(0.086)	(0.079)	(0.075)	(0.120)	(0.130)	(0.130)
corporate tax	1.272**	1.137	1.152*	1.148	0.919	0.826
	(0.147)	(0.096)	(0.090)	(0.320)	(0.213)	(0.182)
IPR	1.789**	1.521*	1.319	1.531	1.283	1.119
	(0.463)	(0.375)	(0.305)	(0.465)	(0.387)	(0.318)
air traffic	1.255**	1.307***	1.185*	1.255**	1.310***	1.194*
	(0.137)	(0.126)	(0.111)	(0.142)	(0.129)	(0.115)
b index				1.110	0.795	0.854
				(0.419)	(0.268)	(0.276)
Time dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Observations	18,318	9,194	7,587	16,389	8,332	6,819
Number of firms	1861	1001	768	1754	955	729
Number of investments	1345	1345	1345	1252	1252	1252

Notes: Coefficients reported are hazard ratios: a coefficient less than 1 indicates a negative effect on the probability to engage in RDDT investments. Models 3 and 6 are for RDDT active firms, models 2 and 5 add a control group of non-RDDT active that do hold patents, and models 1 and 4 add a broader control group of multinational firms.

Table A2.2. The propensity to engage in foreign RDDT investments: city of origin effects and firm effects

	Model1	Model2	Model3	Model3b	Model4	Model5	Model6	Model 6b
technological strength	0.987	1.015	1.027	1.039	0.960	1.025	1.031	1.035
	(0.105)	(0.106)	(0.096)	(0.099)	(0.116)	(0.123)	(0.115)	(0.119)
International R&D. collab.	1.237**	1.135	0.990	0.997	1.322**	1.289**	1.089	1.091
	(0.129)	(0.112)	(0.086)	(0.088)	(0.172)	(0.164)	(0.133)	(0.135)
University strength	0.983	1.020	1.103	1.102	1.109	1.125	1.203	1.203
	(0.111)	(0.115)	(0.118)	(0.119)	(0.163)	(0.167)	(0.173)	(0.173)
gdp	0.862	0.773*	0.835	0.836	1.062	0.963	1.004	1.004
	(0.128)	(0.110)	(0.119)	(0.119)	(0.186)	(0.165)	(0.180)	(0.180)
gdp_gw	1.027	1.026	1.039*	1.040*	1.022	1.025	1.038	1.038
	(0.023)	(0.022)	(0.021)	(0.021)	(0.027)	(0.026)	(0.027)	(0.027)
population density	1.897**	2.060***	1.589**	1.582*	2.386**	2.347**	2.246**	2.239**
	(0.518)	(0.548)	(0.375)	(0.374)	(0.892)	(0.819)	(0.830)	(0.827)
population density sq.	0.924**	0.916**	0.936**	0.937**	0.894**	0.899**	0.895**	0.895**
	(0.035)	(0.033)	(0.030)	(0.030)	(0.044)	(0.041)	(0.042)	(0.042)
wage	1.476**	1.339**	1.315**	1.285*	1.927***	1.763***	1.650***	1.637**
	(0.229)	(0.197)	(0.170)	(0.174)	(0.403)	(0.365)	(0.303)	(0.321)
corporate tax	0.828	0.790	0.719	0.708	1.052	0.935	0.841	0.834
	(0.237)	(0.219)	(0.179)	(0.175)	(0.384)	(0.323)	(0.260)	(0.256)
IPR	1.028	1.274	1.405	1.439	0.936	1.036	0.947	0.953
	(0.423)	(0.538)	(0.561)	(0.572)	(0.503)	(0.585)	(0.472)	(0.480)
air traffic	1.080	1.224	1.105	1.109	0.790	0.879	0.799	0.800
	(0.182)	(0.199)	(0.184)	(0.185)	(0.158)	(0.171)	(0.163)	(0.164)
age	1.007*	1.009**	1.003	1.003	1.001	1.002	0.999	0.999
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
age_squared	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
mediumsized company	0.995	0.743	1.306	1.316				
	(0.277)	(0.194)	(0.280)	(0.283)				
large company	0.736	0.581**	0.992	1.008				
	(0.203)	(0.149)	(0.184)	(0.191)				
verylarge company	1.848***	1.226	1.491***	1.500***				
	(0.376)	(0.221)	(0.212)	(0.216)				
lnpatents	1.200***	1.116***	1.088***	1.090***	1.150***	1.086***	1.070***	1.071***
	(0.027)	(0.027)	(0.023)	(0.023)	(0.031)	(0.030)	(0.027)	(0.027)
turnover					1.265***	1.261***	1.185***	1.185***
					(0.045)	(0.045)	(0.041)	(0.042)
ROA					1.000	1.002	1.001	1.001
					(0.006)	(0.006)	(0.006)	(0.006)
Incoming RDD investments				0.945				0.984
				(0.080)				(0.097)
Time dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Observations	6,493	4,459	2,964	2,964	3,390	2,657	1,946	1,946
Number of firms	949	652	431	431	544	416	299	299
Number of investments	667	667	667	667	481	481	481	481

Notes: Coefficients reported are hazard ratios: a coefficient less than 1 indicates a negative effect on the probability to engage in RDDT investments. Models 3 and 6 are for RDDT active firms, models 2 and 5 add a control group of non-RDDT active that do hold patents, and models 1 and 4 add a broader control group of multinational firms.

ANNEX 3. CO-LOCATION BETWEEN RDDT INVESTMENTS AND OTHER ACTIVITIES ALONG THE VALUE CHAIN AT THE CITY LEVEL

Model

In order to analyse possible co-location effects between RDDT investments and other activities along the value chain, information on prior investments of firms at the city level has been included as explanatory factor in the location choice model (inward RDDT investment) and the propensity model (outward RDDT investment). More detailed information on the used models – respectively conditional/mixed logit model and hazard model – is presented in Annexes 1 and 2.

Variables

The variable *"prior investments"* (firm and city level) is constructed based on cumulative prior investments by firms across cities, using the information in the fDi Markets database. More specifically, information on 2003-2007 investment is used to derive measures of prior investments by firm and city; the models are accordingly estimated for RDDT projects during the period 2008-2011. A distinction is made between count variables *"prior core investments"* (if the prior investments are in the same sector and the main line of business of the investing firms, hence manufacturing or services) *"prior R&D investments"*, *"prior HQ investments"*, *"prior sales & support investments"* and *"prior other investments"*.

An alternative measure of *"prior investment"* was explored upon using firm-level information on worldwide affiliate ownership available in Bureau van Dijk's ORBIS database. The controlling firm behind the RDDT investment project was identified as well as the firm's affiliates in the global cities applying a minimum of 50% ownership to ensure management responsibility and control. Affiliate networks in earlier years were determined using information on the dates of incorporation and if applicable, dates of acquisition or divestment based on information from the Zephyr M&A database. For the affiliates for which city information and NACE information was available, counts of prior investments at the firm-city level were calculated: "prior core affiliates (if the prior affiliates are in the same industry as the investing firms: manufacturing or services), "prior R&D affiliates" (if the NACE code of the affiliate indicates its line of business as R&D) "prior HQ affiliates" (if the line of business is holding company or headquarter activities) and "prior sales & support affiliates" (representing other value chain activities such as call centers, repair services, sales and marketing). Finally there is a rest category "prior other affiliates" for the other affiliates without NACE information.

A number of pitfalls came forward when constructing and using these data. First, for about 20 percent of the affiliates no specific address information was available, such that the number of affiliates in global cities was underestimated. Second, for another 20% of affiliates - in global cities - no NACE information is available: these were grouped in the "other" category. Third and more important, the definition of particular R&D affiliates is necessarily narrow and only includes affiliates dedicated to R&D, rather than affiliates conducting R&D in combination with other mandates (marketing, manufacturing). The same holds for headquarter affiliates. While this method ensured a larger number of observations (compared to using the fDi Markets Database as reported above), it was felt that the quality of the constructed variable on prior investments was much lower. This was confirmed by running the regressions (not reported here) with effects of variables less stable and robust.

Results

Tables A3.1 and A3.2 present the results of the location choice model (inward RDDT projects) when including information on prior investments by firms to assess co-location patterns at the city level. Tables A3.3 and A3.4 present similar results for the propensity model (outward RDDT projects). Tables A3.2 and A3.4 additionally distinguish between industries (engineering-intensive industries in column 1 and RDDT separability in column 2). Because including the variable on prior investments reduces the number of observations because this information is not available for all firms, a comparison model is estimated to examine if estimates change due to sample attrition).

Table A3.1. Determinants of the Location choice of RDDT (all projects) and co-location

	Comparison model		Prior fDI investments	
Variables	clogit	mixed logit	clogit	mixed logit
Technological strength	0.239*	0.257*	0.204*	0.191
	(0.123)	(0.144)	(0.122)	(0.139)
International R&D collaboration	0.231***	0.576***	0.160**	0.441***
	(0.0758)	(0.0884)	(0.0704)	(0.0905)
University strength	0.240*	0.420***	0.244*	0.384***
	(0.133)	(0.140)	(0.127)	(0.133)
GDP	0.356***	0.415***	0.334***	0.474***
	(0.107)	(0.126)	(0.102)	(0.125)
GDP growth	0.0796***	0.0840***	0.0670***	0.0715***
	(0.0132)	(0.0142)	(0.0130)	(0.0145)
Population density	0.444**	0.970*	0.310	1.217*
	(0.205)	(0.552)	(0.205)	(0.728)
Population density squared	-0.0642**	-0.158**	-0.0458	-0.194*
	(0.0297)	(0.0773)	(0.0297)	(0.0999)
Political-social stability	0.231	0.542	0.0267	0.205
	(0.393)	(0.453)	(0.396)	(0.447)
Language similarity	5.498	8.480**	5.078	8.907**
	(3.718)	(4.148)	(3.728)	(4.133)
Geographic distance	0.0431	0.101	0.0132	-0.00409
	(0.0501)	(0.0995)	(0.0509)	(0.0576)
Wage level	-0.785***	-0.863***	-0.722***	-0.781***
	(0.0717)	(0.0952)	(0.0730)	(0.0902)
Corporate tax rate	0.0289	0.0801	-0.0147	0.0314
	(0.101)	(0.111)	(0.100)	(0.118)
IPR protection	1.430***	1.326***	1.360***	1.478***
	(0.338)	(0.389)	(0.351)	(0.393)
Airport traffic index	0.586**	0.172	0.490*	0.0125
	(0.284)	(0.330)	(0.274)	(0.329)
English language proficiency	0.525	1.165**	0.718*	1.122**
	(0.366)	(0.498)	(0.369)	(0.456)
Language similarity*English proficiency	-1.150	-1.854**	-1.053	-1.931**
	(0.840)	(0.927)	(0.842)	(0.932)
Prior core investments			0.134**	0.664***
			(0.0661)	(0.154)
Prior HQ investments			0.385***	0.0719
			(0.149)	(0.291)
Prior R&D investments			0.470***	0.138
			(0.0940)	(0.288)
Prior sales&support investments			0.0185	-0.743
			(0.141)	(0.742)
Prior other investments			0.106	0.112
			(0.175)	(0.368)
Random parts coefficients				
International R&D collaboration		0.976***		0.906***
GDP		0.606***		0.639***
geographic distance		0.351*		
prior core investments				1.679***
prior HQ investments				2.713***
prior R&D investments				1.199***
Observations	44,329	44,329	44,329	44,329

Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1
GDP growth only has a fixed component in model 2.

Table A3.2. Determinants of the Location choice of RDDT (all projects) and co-location by type of industry

Variables	Prior FDI	Prior FDI
Technological strength	0.191	0.192
	(0.122)	(0.123)
International R&D collaboration	0.153**	0.155**
	(0.0696)	(0.0698)
University strength	0.251**	0.251**
	(0.127)	(0.127)
GDP	0.335***	0.335***
	(0.102)	(0.103)
GDP growth	0.0670***	0.0663***
	(0.0130)	(0.0130)
Population density	0.321	0.313
	(0.207)	(0.205)
Population density squared	-0.0479	-0.0466
	(0.0300)	(0.0297)
Political-social stability	0.0423	0.0393
	(0.399)	(0.395)
Language similarity	4.778	4.916
	(3.709)	(3.719)
Geographic distance	0.0130	0.0127
	(0.0502)	(0.0503)
Wage level	-0.723***	-0.726***
	(0.0725)	(0.0727)
Corporate tax rate	-0.0140	-0.00471
	(0.100)	(0.101)
IPR protection	1.363***	1.358***
	(0.351)	(0.351)
Airport traffic index	0.499*	0.489*
	(0.275)	(0.275)
English language proficiency	0.682*	0.702*
	(0.370)	(0.368)
Language similarity*English proficiency	-0.986	-1.018
	(0.838)	(0.840)
Prior core investments	0.347***	0.643***
	(0.119)	(0.0879)
Prior HQ investments	0.150*	0.115**
	(0.0882)	(0.0576)
Prior R&D investments	0.245	-0.0855
	(0.184)	(0.185)
Prior sales&support investments	0.494***	0.238
	(0.178)	(0.210)
Prior other investments	0.414**	-0.196
	(0.179)	(0.254)
industry type:	*high engineering*	*separable RDD*
prior core investments * industry type	0.286*	-0.320**
	(0.151)	(0.138)
prior HQ investments * industry type	-0.0398	0.0687
	(0.0997)	(0.0968)
prior RDD investments * industry type	-0.468*	0.231
	(0.258)	(0.274)
prior up/downstream investments * industry type	-0.182	0.399
	(0.319)	(0.286)
prior other investments * industry type	-0.484	0.693**
	(0.317)	(0.308)
observations	44,329	44,329

Note: Results of conditional logit models. Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A3.3 The propensity to engage in foreign RDDT investments and co-location

	Model 1	**Model 2**	**Model 3**
technological strength	0.864	0.901	0.918
	(0.111)	(0.115)	(0.112)
International R&D. collab.	1.239	1.173	1.022
	(0.168)	(0.159)	(0.134)
University strength	1.176	1.227	1.305
	(0.195)	(0.206)	(0.221)
gdp	1.152	1.060	1.046
	(0.217)	(0.187)	(0.187)
gdp growth	1.017	1.020	1.031
	(0.027)	(0.027)	(0.027)
population density	2.804**	2.860**	2.710**
	(1.208)	(1.185)	(1.286)
population density sq.	0.890**	0.888**	0.885**
	(0.049)	(0.047)	(0.052)
wage	1.792**	1.624*	1.528*
	(0.467)	(0.415)	(0.362)
corporate tax	0.902	0.833	0.783
	(0.370)	(0.328)	(0.301)
IPR	0.954	1.165	1.137
	(0.611)	(0.799)	(0.742)
air traffic	0.793	0.870	0.856
	(0.176)	(0.185)	(0.199)
age	1.004	1.005	1.002
	(0.004)	(0.005)	(0.003)
age squared	1.000	1.000	1.000
	(0.000)	(0.000)	(0.000)
turnover	1.194***	1.173***	1.111**
	(0.054)	(0.052)	(0.049)
firm patents	1.105***	1.049	1.046
	(0.039)	(0.035)	(0.034)
ROA	1.011	1.011	1.010
	(0.009)	(0.008)	(0.008)
prior core investment	1.003	1.003	1.000
	(0.002)	(0.002)	(0.002)
prior RDD investment	1.081***	1.081***	1.063***
	(0.026)	(0.023)	(0.022)
prior up/downstream inv.	1.000	1.002	1.002
	(0.011)	(0.010)	(0.009)
prior other investment	0.993	0.997	1.007
	(0.007)	(0.007)	(0.010)
time dummies	INCLUDED	INCLUDED	INCLUDED
Observations	2,379	1,858	1,360
Number of firms	524	402	291
Number of investments	314	314	314

Notes: Coefficients reported are hazard ratios: a coefficient less than 1 indicates a negative effect on the probability to engage in RDDT investments. Model 3 are for RDDT active firms, model 2 adds a control group of non-RDDT active that do hold patents, and model 1 adds a broader control group of multinational firms.

Table A.3.4. The propensity to engage in foreign RDDT investments and co-location by type of industry

	Model 1	Model 2
technological strength	0.902	0.924
	(0.109)	(0.112)
International R&D. collab.	1.011	1.031
	(0.133)	(0.133)
University strength	1.284	1.292
	(0.218)	(0.230)
gdp	1.058	1.060
	(0.183)	(0.186)
gdp growth	1.035	1.032
	(0.027)	(0.027)
population density	3.143**	2.961**
	(1.545)	(1.471)
population density sq.	0.868**	0.875**
	(0.052)	(0.054)
wage	1.588*	1.553*
	(0.393)	(0.373)
corporate tax	0.676	0.735
	(0.258)	(0.275)
IPR	0.891	1.104
	(0.561)	(0.725)
air traffic	0.852	0.841
	(0.195)	(0.197)
age	1.001	1.002
	(0.003)	(0.003)
age squared	1.000	1.000
	(0.000)	(0.000)
turnover	1.114**	1.118**
	(0.050)	(0.049)
firm patents	1.056*	1.047
	(0.033)	(0.035)
ROA	1.008	1.011
	(0.007)	(0.008)
prior core investment	0.999	1.000
	(0.004)	(0.002)
prior RDD investment	1.120***	1.069**
	(0.022)	(0.036)
prior up/downstream inv.	0.971	1.005
	(0.020)	(0.014)
prior other investment	0.996	1.001
	(0.019)	(0.014)
industry type:	*high engineering*	*separable RDD*
prior core investment * industry type	1.005	0.999
	(0.005)	(0.011)
prior RDD investment * industry type	0.922***	0.997
	(0.028)	(0.040)
prior up/downstream inv. * industry type	1.047**	0.986
	(0.023)	(0.020)
prior other investment * industry type	1.000	1.009
	(0.023)	(0.020)
time dummies	INCLUDED	INCLUDED
Observations	1,360	1,360
Number of firms	291	291
Number of investments	314	314

Notes: Coefficients reported are hazard ratios: a coefficient less than 1 indicates a negative effect on the probability to engage in RDDT investments. Models include only RDDT active firms.

ANNEX 4. RDDT INVESTMENTS ABROAD AND INNOVATIVE ACTIVITIES AT HOME

Model

In order to analyse the impact of RDDT investments abroad on the innovation activity at home, the following model is used relating foreign RDDT investments to changes in patent activity in the home city:

$$\Delta p_{i,j}=\alpha+\beta RDDT_{t-1}+\gamma\Delta P_j+\delta\Delta p_{i,j,t-1}+\theta X_{j,t-1}+\vartheta Z_{i,t-1}+e_t \quad (1)$$

where

RDD_{t-1} = cross-border RDDT investments by firm i in the prior year;
ΔP_j= the change in the total number of patents invented in city j in the sector of the firm;
$\Delta p_{i,jt-1}$= the change (t-1, t-2) in the number of patents invented by firm i in its home city j in the prior period;
$X_{j,t-1}$= lagged other relevant variables in region or country j (e.g. technological strength, tax levels);
$Z_{i,t-1}$= lagged other firm characteristics (firm size and age);
e_{it}= $\mu_{it}+\varepsilon_t$ an error term consisting of a firm-specific element μ_{it} and a random term ε_t.

Equation (1) models the growth in patenting in a firm's home city as a function of prior RDDT investments and two key control variables: 1) the growth in the total number of patents invented in the city in the firm's sector during the same period (t-1 to t), to control for unobserved contemporaneous changes in the city environment and sector that have led to overall increases or decreases in patenting in the city; 2) patent growth of the firm in the city in the prior year (t-2 to t-1) to control for observed firm-specific characteristics that have led to RDDT expansion.[4] In addition, a number of basic firm-level controls are included that were used in the empirical analysis in Section 4.

As the (change in the) number of patents is a count variable, estimation requires the use of count data models. In order to ensure that the dependent variable maintains positive values (required for count data models), equation (1) is rewritten into equation (2) which itself is estimated with negative binomial regression, with firm-level random effects μ_{it}.:

$$\Delta p_{i,j}=\alpha+\tau p_{i,jt-1}+\delta\Delta p_{i,j,t-1}+\beta RRDDT_{t-1}+\gamma\Delta P_j+\delta X_{j,t-1}+\delta Z_{i,t-1}+e_t \quad (2)$$

Attempts have been made to experiment with different lags between RDDT investment and patent growth, by relating average patent number in the home cities over 2 or 3 years (from t to t+1 or t+2) to prior RDDT (in t-1). This however resulted in significantly smaller numbers of observations making the analysis less robust.

The analysis is done at the firm-year level and relates changes in the number of patents invented by the firms in their home cities to prior RDDT investments abroad. The sample consists of firms:

1. for which foreign RDDT investments are recorded during the period 2003-2010;
2. that have their home base in one of the 57 global cities under study;
3. that have applied for PCT patents during the period 2002-2011
4. that have RDDT operations in their home city (as indicated by patent applications with inventors in the city);
5. that have consistent information on firm level characteristics (firm size and age)

In particular criteria 2 and 3 lead to attrition of the sample, whilst most firms that patent and are based in the global cities have RDDT operations in their home city. Application of the criteria leads to a sample of 181 multinational firms based in 35 cities. Patent data for these firms are observed up to the year 2011. As the PATSTAT edition of 2013 to retrieve patent data is used and there are PATSTAT publication delays of 1-2 years, the number of patents counted in 2012 suffers from severe truncation. Since patent growth to prior RDDT and RDDT data are available starting in 2003, the period of analysis is 2004-2011 (a panel of 8 years).

Variables

The dependent variable is the number of home city patents invented by the firm in year t. Based on the patent data which are constructed at the consolidated firm level in order to have a complete description of firms' global inventive activities, inventor location information disclosed on patents is exploited to examine where inventive activities -leading to patent applications- take place. In the absence of information on RDDT projects in the home country (fDi Markets only covers cross-border investments), patent data provide a second best solution to identify trends in innovation activities in the home country or region. Patenting activities may be most representative of the research part of RDDT, while development and design activities less often translate into patents.

The number of patents of the firm in the home city in year t-1 is included as an explanatory variable. Firms' prior patent growth in the home city is the change in the number of firm patents invented in the home city in the prior period. City patent growth is the growth in the number of patents invented in the city in the industry of the focal firm between t-1 and t; the difference in counts is expressed as a logarithmic specification: $\Delta P_j = lnP_{jt} - lnP_{jt-1}$.

The key independent variables relate to prior RDDT investments abroad by the sample firms. Distinction is made between investments with a focus on Research, or Research and Development (RRD) and investments focusing on development (only), or design and testing (DDT). In addition, the model distinguishes between investments in advanced countries and investments in emerging economies (based on classification used in IMF's *World Economic Outlook*), including in the models the share of emerging economies in the RRD and DDT investments of the firm.

Other firm level variables include are age and size, as defined Annex 3.

Results

Model 1 in Table A4.1 concerns a base model only including the growth and prior patent variables; the significantly positive coefficient for prior patents of the firm shows that patenting rates are moderately stable over time: a 1% higher patenting rate in t-1 is associated with up to 0.6% higher patent rate in year t. Prior patent growth rates (t-2 to t-1), on the other hand, have no significant association with current patenting rates, indicating that there is no stable pattern in terms of patent growth. Further on the results show that firms' patent rates are neither significantly associated with the overall growth in patenting in the firms' industry in the city, overall suggesting that most variation in firms' patent rates are due to firm-specific factors.

Models 2, 3 in Table A4.1 include respectively all RDDT investments abroad, only research and R&D (RRD) investments and only development, design and testing (DDT) projects. Model 4 additionally includes the share of RDDT investments in emerging economies. Models 5, 6 and 7 include firm characteristics.

Table A4.1. Foreign RDDT investments and changes in firms' patenting in their home cities

	model1	model2	model3	model4	model5	model6	model7
Patent count t-1	0.5750***	0.5816***	0.5798***	0.5798***	0.5729***	0.5714***	0.5716***
	(0.0270)	(0.0272)	(0.0271)	(0.0272)	(0.0280)	(0.0279)	(0.0280)
Prior patent growth	0.0412	0.0427	0.0439	0.0436	0.0491	0.0501	0.0499
	(0.0312)	(0.0312)	(0.0313)	(0.0313)	(0.0315)	(0.0315)	(0.0316)
City patent growth	0.0035	0.0016	0.0043	0.0049	-0.0008	0.0021	0.0028
	(0.0640)	(0.0642)	(0.0643)	(0.0643)	(0.0642)	(0.0643)	(0.0643)
Age					0.0018	0.0018	0.0018
					(0.0022)	(0.0023)	(0.0023)
Age squared					-0.0000	-0.0000	-0.0000
					(0.0000)	(0.0000)	(0.0000)
Medium-sized company					-0.4260	-0.4295	-0.4315
					(0.4037)	(0.4045)	(0.4046)
Large company					-0.3254	-0.3298	-0.3317
					(0.4012)	(0.4020)	(0.4021)
Very large company					0.1140	0.1154	0.1128
					(0.2487)	(0.2493)	(0.2496)
Prior RDD		0.0972***			0.0931**		
		(0.0375)			(0.0372)		
Prior RRD			0.0327	0.0372		0.0332	0.0408
			(0.0482)	(0.0586)		(0.0474)	(0.0573)
Prior DDT			0.1055**	0.1084**		0.1010**	0.1018**
			(0.0428)	(0.0490)		(0.0424)	(0.0485)
Share of RRD in EM				-0.0104			-0.0174
				(0.0756)			(0.0742)
Share of DDT in EM				-0.0072			-0.0013
				(0.0658)			(0.0652)
Time dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Constant	-0.8486***	-0.8885***	-0.8762***	-0.8764***	-1.0792***	-1.0685***	-1.0678***
	(0.1274)	(0.1288)	(0.1281)	(0.1284)	(0.2578)	(0.2580)	(0.2582)
Observations	1,405	1,405	1,405	1,405	1,405	1,405	1,405
Number of firms	181	181	181	181	181	181	181
Log likelihood	-4004	-4001	-4001	-4001	-3996	-3996	-3996
chi2	526.6***	528.6***	532.7***	532.8***	552.2***	555.8***	555.5***

Notes: Results of Negative Binomial panel data models with random effects.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

ANNEX NOTES

1 See http://www.oecd.org/regional/redefiningurbananewwaytomeasuremetropolitanareas.htm.

2 The PCT provides a unified procedure for filing patent applications to protect inventions in each of the contracting states of the PCT. Accordingly, patent applications filed under the PCT can be considered as international patent applications.

3 A drawback of the B-index is that it does not take into account R&D subsidies, which may also differ across regions.

4 The latter variable does not include city patents applied for by the focal firm.